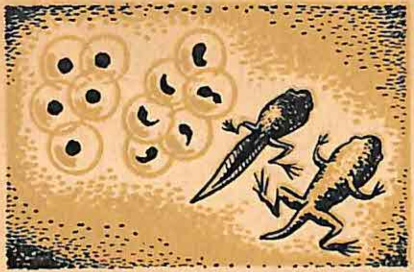

SCIENCE ON THE MARCH

Unit 12

BIRTH AND GROWTH

SCIENCE ON THE MARCH

UNIT TWELVE

BIRTH AND GROWTH

General Editor : **Charles H. Dobinson**

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First published in Great Britain 1960
Second Impression 1961

This unit has been especially written for SCIENCE ON THE MARCH by Charles H. Dobinson, M.A., B.Sc., Professor of Education in the University of Reading, who is the general editor of this series.

The first 13 units of SCIENCE ON THE MARCH are:

1. The Air and You.
2. Water and Life.
3. The Weather and the Earth.
4. Life and Food.
5. Health.
6. Energy and Engines.
7. Hearing and Seeing.
8. Electric Currents.
9. Magnets and Electric Power.
10. Earth and Universe.
11. Heating and Cooling.
12. Birth and Growth.
13. Metals and Man (*in preparation*).

Made and printed in Great Britain by Butler & Tanner Ltd., Frome and London

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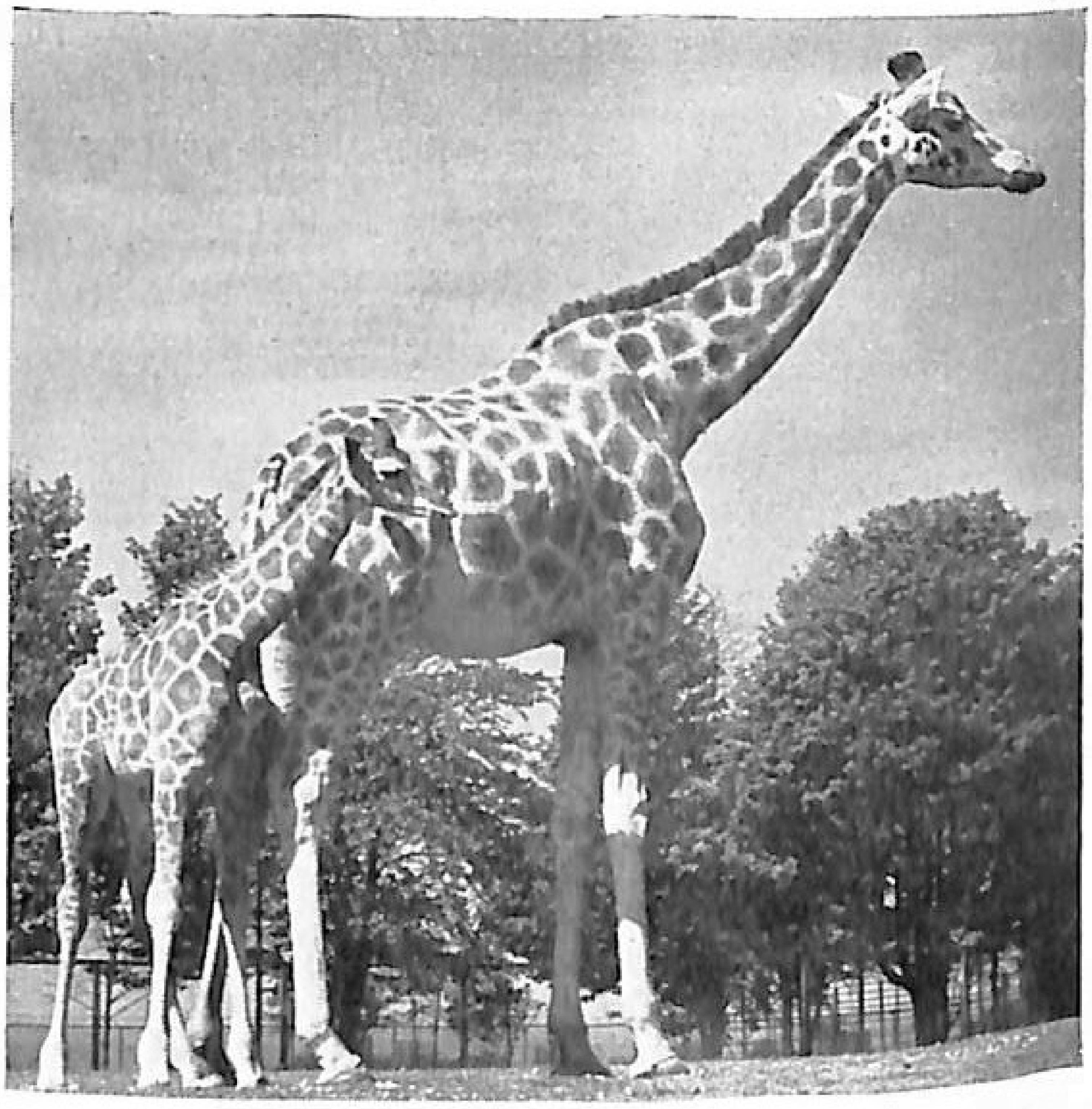
BIRTH AND GROWTH



Birth and Growth

YOUNG people are usually very fond of their grandparents. Partly, no doubt, this is " cupboard love " since grandparents are very kind and generous, especially at Christmas time and birthdays. But mainly this affection is based on something very much deeper, the mutual regard of a united family. In addition there are often real resemblances between young people and their grandparents. There may be musical ability, artistic ability, or mathematical ability, which has " skipped " a generation and reappeared in grandchildren. Or there may be astonishing little body likenesses between grandparent and grandchild—such as the nature of the hair, the shape of the ears, a " mole " on the same position of the neck, or even a peculiar physical habit such as a slight upward movement of the right eyebrow when the person is feeling strained. Can you think of such instances in your own family ? All this " transmission " of abilities and characteristics is part of the amazing story of human life, with its big events of birth, growing up, marriage, the begetting of children, the coming of grandchildren and, finally, death.

Perhaps our own grandparents are now rather wrinkled, they may be a little deaf or bald : anyway it is hard for us to realize that some sixty or seventy years ago these grandparents were helpless tiny babies, and that no one then had thought about either our parents or ourselves.

But here we are, and we want to understand what we can about life, so let us consider some of the questions we ought to ask about babies.

The photographs on the opposite page are by W. Suschitzky

Problem A: **WHAT SHOULD WE KNOW ABOUT BABIES?**

Question I. **Where did I come from?**

Probably every one of us asked our mother this question when we were very young, but now we have forgotten what she told us. Perhaps she said something like this: "You came from inside me, where you grew from a tiny speck smaller than any garden seed, and you took nine months to grow." The growth took place inside the elastic cradle called the *womb*. In this the developing baby is surrounded with fluid, partly to protect it against injury and partly to keep it always at the right temperature. In the earliest stages of growth, before the limbs are formed, the future baby is known as the *embryo*—from a Greek word meaning "to swell." After a certain stage, the growing process is very much a process of swelling.

But how does the future baby get food in order to grow? The answer is that the food is conveyed in liquid form dissolved in the blood of the mother. A sort of pad develops on the inner wall of the womb and acts as an absorbing sponge that takes food from the mother's blood. From this pad there grows a tube to the future baby. When the baby is born, the tube is cut by the doctor or nurse, and the place where the tube joined is marked by the *navel*. "Being born" means being pushed out of the womb by increasingly powerful rhythmic contractions of the muscles. This process usually takes some hours and a woman who is giving birth to a child is said to be "in labour." Modern science has made the birth of children a safe and sometimes an almost painless matter for the mother, but it is always desirable that a doctor and a "midwife," a maternity nurse, should be present to help if necessary in the "delivery" of the baby and to look after both mother and child.

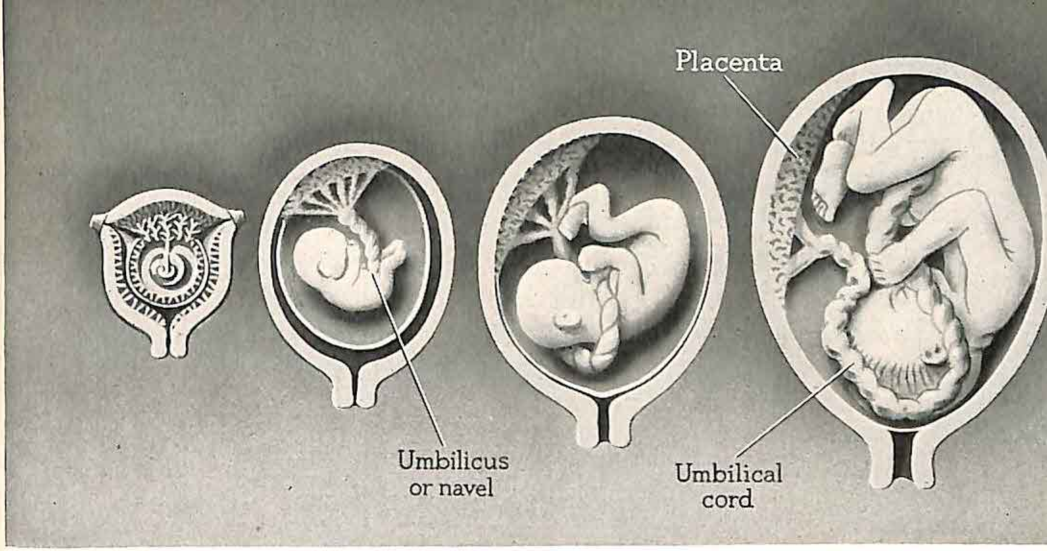


FIGURE 2. A human embryo at stages of 2, 4, 6 and 9 months.

After the baby is born the spongy pad comes away from the wall of the womb and is expelled, and then the mother's womb grows small again, as it was before the baby started to grow.

About nine months before the child is born, at the very first microscopic stages of the growth of a new embryo inside the womb, all sorts of chemical messages reached different parts of the body of the future mother. For instance, the blood stream began to prepare itself for the demands of the nine months of nourishing the growing embryo, and her breasts began to prepare themselves for giving milk to the baby after birth. It is not surprising, therefore, that every "expectant" mother needs a certain amount of extra care. It is important that she should have enough good food because the growing child she carries is making demands which must be satisfied. If the child's requirements are not met by adequate and suitable foods eaten by the mother, then Nature will see that they are supplied from the reserves in the mother's own body. We know

now that there is no reason why a mother's teeth or hair, for example, need suffer in any way from having to cater for an extra life within, provided that the mother's diet includes extra food of certain sorts.

This is one reason why expectant mothers go regularly to special *pre-natal clinics* where they can get the help and advice that is so important to the well-being not only of the future babies but also of themselves.

SOME THINGS YOU MAY CARE TO DO

1. Keep your eyes open for animals that are going to give birth to young and be extra kind to them. Female cats usually have more than one litter every year, so you will often see a cat with a very swollen body. Such a cat should always be given a warm comfortable spot in which to have her kittens.

2. If you keep rabbits you will notice how the mother rabbit plucks fur from the underside of her own body to make a nest in which her babies, which are born blind and without fur, can be kept warm.

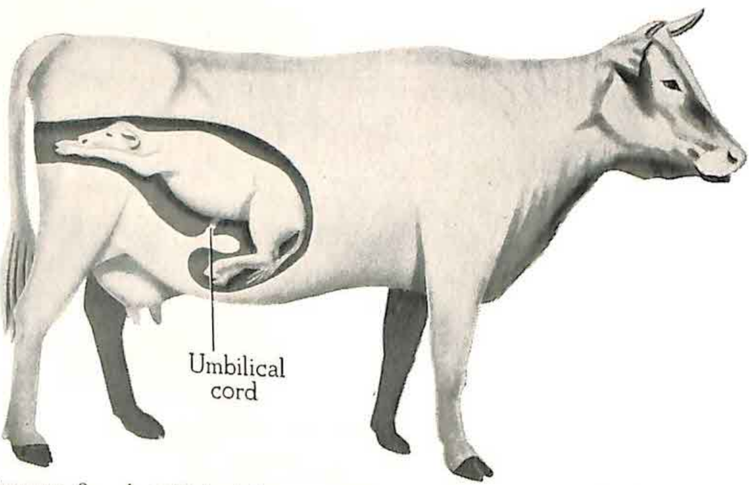


FIGURE 3. A calf just before birth. Note the short umbilical cord.

3. When you are in the country look out for cows that are "in calf," mares that are "in foal," pigs that are "in farrow," sheep that are "in lamb." Find out what the farmer has to do to look after these animals, before, during, and after the time that they give birth to their young.

4. With the other members of your class you can do something to spread knowledge regarding the care of the young of animals. Write to the Royal Society for the Prevention of Cruelty to Animals, 105 Jermyn Street, London, S.W.1, and arrange to receive every month one or two class copies of the illustrated magazine *The Animal World.* There are also pamphlets such as *The Care and Treatment of Puppies* and *How to look after the Cat.* The Society also lends films.

You can obtain helpful leaflets on the care of your dog, your cat and of rabbits, guinea-pigs, golden hamsters and mice from the People's Dispensary for Sick Animals, P.D.S.A. House, Clifford Street, London, W.1.

The Universities Federation for Animal Welfare, 7A Lamb's Conduit, London, W.C.1, lends films, film-strips and display photographs, and will tell you about their printed "lecturettes" on various animals.

5. You can obtain more information about the birth of a baby from a pamphlet called *How We Grow up,* supplied by The Central Council for Health Education, Tavistock House, London, W.C.1.

Question 2. **Why do we have Fathers as well as Mothers?**

Nature is so arranged that every sort of animal or plant shall, in the words of the Bible, "bring forth young after its kind." We have already learnt from Unit 4, LIFE AND FOOD, that our bodies and those of the larger animals contain millions and millions of *cells*. Every individual cell is so small that we can only see it if we use a microscope.

From an early stage in the lives of every one of us some cells have been specially concerned with providing for the birth of a new generation. In the bodies of girls and women there develop organs called *ovaries* (from a Latin word meaning an "egg") which produce

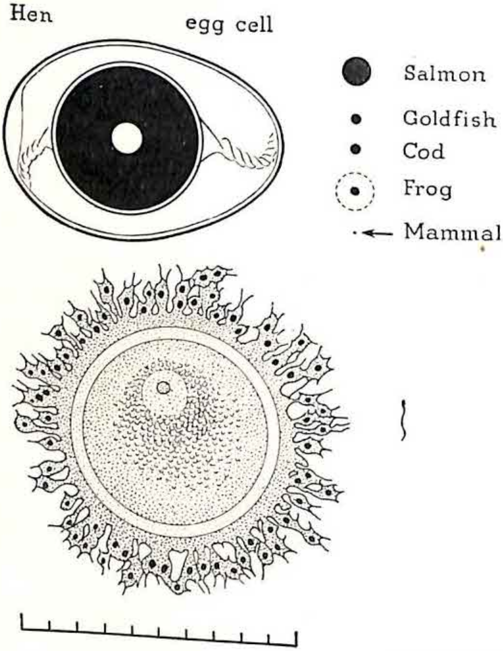


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FIGURE 4. At the top the size of a hen's egg is compared with that of some other eggs. The lower picture shows a human egg cell and human male cell highly magnified, every division of the line representing one thousandth of an inch.

egg-cells from which a future baby may grow. These egg-cells are only one-fifth of a millimetre in diameter, about the size of the full stop at the end of this sentence.

If these egg-cells could develop on their own, it is probable that all children of the same mother would be exactly like one another—like motor-cars from one conveyor belt, or shrubs raised from cuttings taken from the same bush.

But in most animals and most plants these egg-cells cannot develop on their own. Before an egg-cell can start to split into two and so multiply, a process called " fertilization " has to take place. As a general rule, but with exceptions, no egg-cell that has not been fertilized can multiply and so develop into an embryo. Later in this Unit we shall learn how this happens.

For human beings the process of fertilization is basically the same as for most animals and most plants. The material from a quite different sort of cell, a *male* cell, has to be joined with the female egg-cell before growth (i.e. division and multiplication of cells) can take place.

When a scientist examines under a very strong microscope a dividing cell from almost any part of a human body, he finds in it precisely 46 tiny rods called *chromosomes*. But when he examines a female egg-cell, he finds that in it there are only 23 chromosomes. Similarly, if the scientist examines a male cell, which is the equivalent of the egg-cell of a female, he will find in it only 23 chromosomes. These male cells, very very much smaller than the female egg-cells, are called *sperm* cells (from a Greek word meaning " seed "). They are produced in the male sex organs known as the testicles. Only after one of these cells has joined with an egg-cell will the fertilized egg-cell (which now has in it a full set of 46 chromosomes) begin to develop into an embryo.

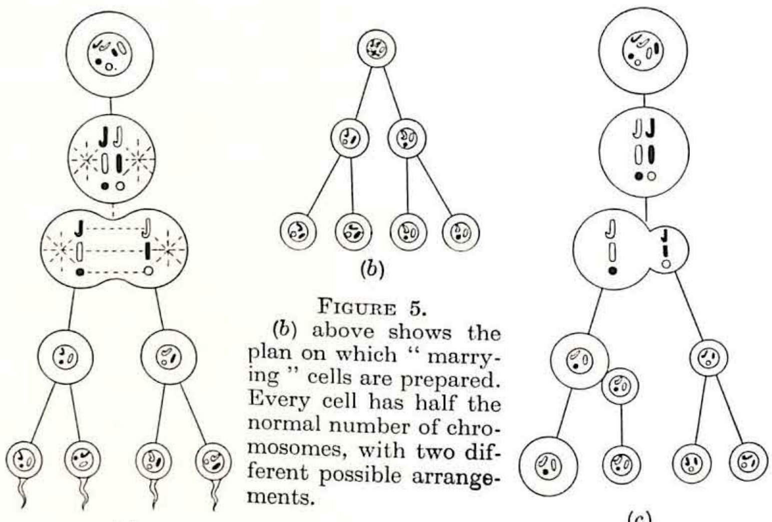


FIGURE 5.
(b) above shows the plan on which "marrying" cells are prepared. Every cell has half the normal number of chromosomes, with two different possible arrangements.

Redrawn from Haldane & Huxley: "Animal Biology," by permission of the Clarendon Press

(a) shows how four small sperms of equal size are formed. In (c) only one large egg-cell is formed and the three small cells ("polar bodies") die away.

These microscopic chromosomes are immensely important, for they carry, in pairs of almost inconceivably minute particles, all the characteristics which a baby inherits from his father and mother. The factors carried by these particles are called *genes*. If a baby got all its genes from its mother's egg-cell only, it would grow up in many ways exactly like its mother. If the mother had brown eyes and wavy hair, the baby would have brown eyes and develop wavy hair. But, because there has to be a father too, each baby has, as it were, a new deal of playing cards, half a set from its mother and half a set from its father. The genes, of course, are vastly more numerous than playing cards and every combination of one half pack with another half pack is different from any other. The result is that the brand-new living being is in some ways like its father, in some ways like its mother, in some ways

like both its parents, and in other ways unlike either parent. The new baby is, in fact, an *individual*, unique, different in its combination of inherited characteristics from any other individual that has ever lived. Even its fingerprints are unique, and the police have made good use of this fact for a long time. All this uniqueness of the individual is the very complicated work of the chromosomes. Once the deal has been dealt, once the fertilized egg-cell has its own original collection of genes in its chromosomes, then every new cell in the growing body keeps just the same collection from birth to death.

One sentence above is not quite exact. Sometimes we meet two brothers or two sisters who are "identical twins." But they are identical in their inherited characteristics just because they have happened to be produced together from *one* fertilized egg-cell. This is not a very common occurrence among human beings, but it is of great interest to many kinds of scientists: can you think why?

FIGURE 6. Two identical twins at the age of 14. Can you see differences between Edward on the left and Leonard on the right?
Fox Photos

The importance of the human father is by no means limited to providing half of the chromosomes for the future embryo which will develop from a fertilized egg-cell. We have already seen that the expectant mother needs special care and protection. The mother with young children equally needs protection, food and help.

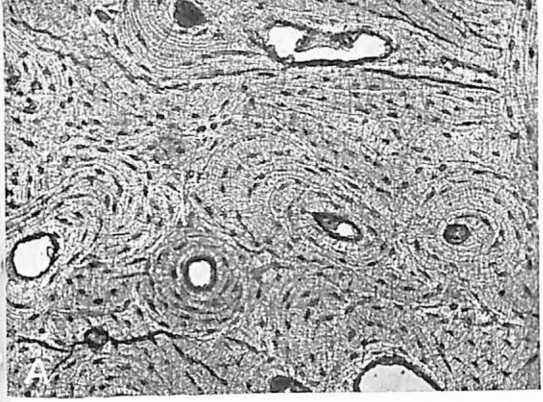
In primitive tribes the father acts as the protector of his wife and his family against wild animals. He is also the hunter who brings in the food. He trains his son to fish and to track game, to fell trees and to build huts, to ford or to swim rivers, and to do the other things for which the greater muscular strength of the male has fitted him.

In modern life, just as in primitive tribes, one of the purposes of the father is to be protective, and to give to the mother, and also to her babies, a feeling of security. Indeed, it is only by studying the development of young children that men and women have come to realize how important it is for babies to have this feeling of security. While it is true that many of the finest men and women who ever lived lost their father by death when they were small, yet it is always much easier for a child to grow up into a fine and worthy person if he or she is a member of a happy family with a father to play his protective part.

SOME THINGS YOU MAY CARE TO DO

1. Prepare a talk for your class on fingerprints: a good encyclopaedia will probably help you in this.

2. If you want to know more about chromosomes and the part they play in the crossing of different kinds of animals and plants, turn to the words *chromosomes,*



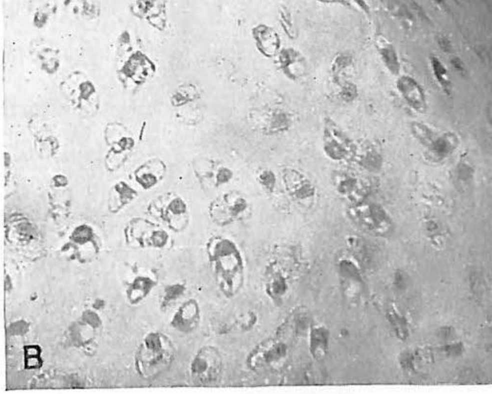


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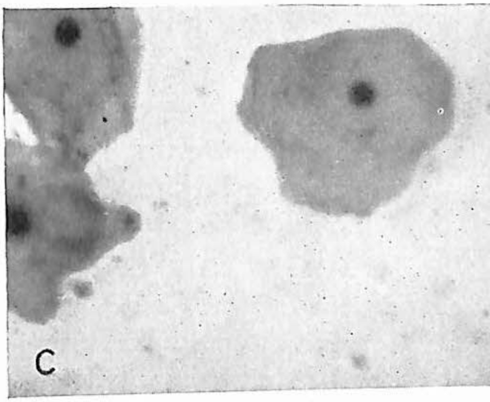
FIGURE 7.

(*a*) A section through human bone. The holes are blood vessels and the dark dash-like marks are bone cells. (× 80.)

(*b*) a section through cartilage (× 320) of a cat, showing cartilage cells, mostly in pairs.

(*c*) Some cells lightly scraped from inside of human cheek and stained (× 425). The dark spot is the nucleus.



Mendelism, *heredity*, *genes* in an up-to-date encyclopaedia or biology text-book.

3. Refresh your mind regarding the different types of cell to be found in the human body. Look at Figure 7 which shows you some very different types of cell, though they are not all magnified to the same degree.

4. Sex cells are very sensitive to radiations such as X-rays and rays from radioactive elements. Tests with animals and plants have shown that damage to sex cells may result in deformed young. There is a danger that human beings may suffer from the radiations resulting from testing nuclear weapons. See if, with the help of your librarian, you can find up-to-date scientific information on this subject so as to give a talk to your class. You can also obtain information from the World Health Organization, Geneva.

Question 3. **What special Care do Babies need ?**

We have already read that before a baby is born its mother's body gets ready to supply the baby with milk. When a baby's mouth is put against the nipple of its mother's breast it soon begins to suck. It does not have to be taught to suck and this is a blessing, for otherwise it might die before it could be taught to feed in this or in some other way.

Milk provided from its mother's body is the best of all foods for the new baby, for it contains all that a baby needs for the first weeks. Not all mothers are able to feed their babies with adequate quantities of milk, especially if they have too much work to do or are not in good health. So these mothers feed their babies from a bottle with milk food made largely from cow's milk. This is not quite as good as the mother's milk, so doctors always encourage mothers to feed their babies themselves if they can.

A few months after birth, a baby reaches the stage of growing teeth. Then the baby begins to want new foods more solid than milk. It is essential that at this stage the baby should have adequate quantities of the right minerals and of the right vitamins ; if the baby does not get them, the milk teeth will not be formed properly or will not be strong enough to resist disease. Did you have to receive attention from the dentist for any of your milk teeth ? Perhaps when we are more skilled in looking after our homes and our children and providing them with the right sort of diet, there may be far less dental decay among boys and girls who are at school. The trouble is not entirely a matter of diet, however, and some children seem to inherit from their parents a tendency to have strong teeth or weak teeth.

The head is another part of a baby's bony structure that needs special care in the early years. In the first few months of its life the bones that make the "brainbox" or *cranium* are still somewhat soft and have not fully joined together. So great care must be taken not to let the baby fall and hit its head.

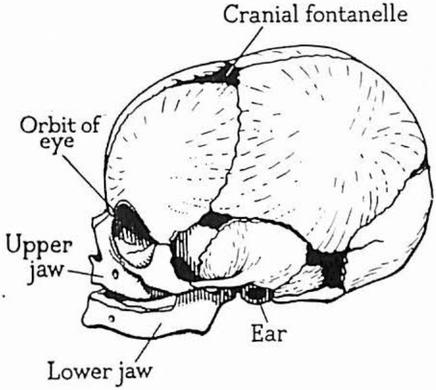


FIGURE 8. The skull of a child, before the bones have fully joined.

Also, although a baby can grip your finger very tightly indeed, not all the muscles of its arms and wrists are strong in its early weeks. So, if a baby turns itself over on to its face in its cot, it is not able to turn itself back again. This is why a young baby should never be given a soft feather pillow, for the baby may smother itself in it. Many babies do smother themselves every year in this way, though fortunately the number is growing less every year as schools and clinics teach future parents more about the proper care of their little ones.

Babies are naturally very delicate in many ways. Not long ago babies used to get all sorts of diseases in their first few months and very many of them died in their first year of life. For instance, John Wesley was the fifteenth of nineteen children of whom eight died

W.H.O.

FIGURE 9. Malnutrition of both mother and child have caused this Indonesian baby to go blind. A few spoonfuls of cod liver oil, if given early enough, could have saved its sight.

in infancy. In which century was John Wesley born? Even as recently as ten years ago, over 40 babies out of every thousand born alive in England and Wales died within the first twelve months. In 1957 the figure for England and Wales was 25, for the Netherlands it was 20, for Sweden 17.

But babies need more than the right amounts of food and air and sunlight and sleep in order to grow up as happy, healthy little beings. Just as important as any of these is love. Psychologists and other people who have studied the human mind have found out that it is very difficult for children who are neglected or unloved in babyhood to grow up into people with fine characters and generous kindly natures. Indeed it is almost impossible to overestimate the importance of the first five or six years of a child's life. Some young fathers and mothers do not realize this fact, and so do not give all the help they should in laying the foundations of a fine new individual. Both father and mother have a great part to play in helping the young child to feel at home in a very strange world, to feel wanted and loved and secure.

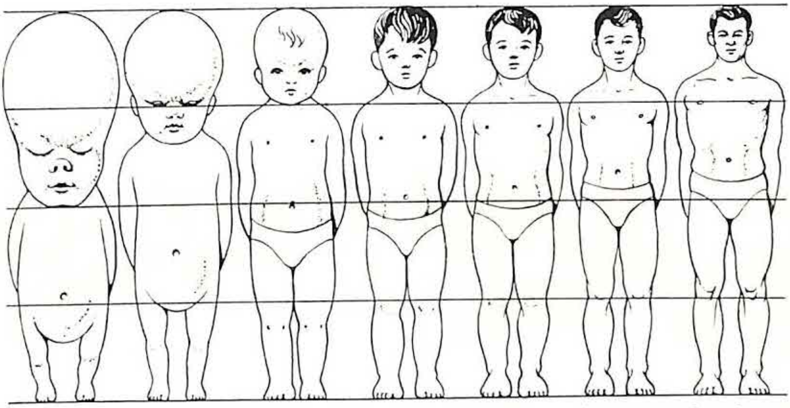


FIGURE 10. The relative size of head to body from the stage of embryo and newly born child to adult.

SOME THINGS YOU MAY CARE TO DO

1. It is a good thing for young people, boys as well as girls, to visit a nursery school. See if your teacher can arrange for small groups of three or four to spend a morning at such a school. To learn anything from such a visit you must be very quiet and unobtrusive: then you can observe carefully the behaviour of the children when they are doing things together and playing by themselves.

2. If you are a member of a girls' school perhaps your teacher can also arrange for small parties to pay visits to a local crèche to observe the care given to babies and to find out something about the supply of vitamins and other food needs of babies.

3. Most advanced countries now have special arrangements for the care of babies, and children's allowances to help the parents to feed and clothe their children properly. If you have a pen pal in any of the following countries, see what you can find out about arrangements for helping parents with babies and children: Belgium, Denmark, France, Germany, the Netherlands, Norway, Sweden, Switzerland, the United States.

Problem B: HOW ARE SOME YOUNG ANIMALS BORN? HOW ARE THEY FED AND TRAINED BY THEIR PARENTS?

Why are human beings almost always interested in the young of other animals? Perhaps you can suggest some reasons. Certainly most people do like to watch puppies, kittens, foals, lambs, and chicks.

So let us consider the young of several groups of animals.

Question 1. What do we know about baby Mammals and the training they receive from their Parents?

Most of us know that those gigantic sea creatures we call *whales* are not fishes but are mammals. But we may not have stopped to think what the word *mammal* means. The name comes from a Latin word that means a "teat." So a mammal is a type of creature in which the female has teats and suckles its young, i.e. it gives milk to its young when they suck.

All mammals have a certain amount of hair at some stage of their lives. Also all mammals are quadrupeds, i.e. have four legs, or two arms and two legs. But the whales are an exception, for though their fore limbs are well developed as flippers, there is no actual hind limb, but only traces of the bones to which the limb could have been joined.

Most mammals develop their young inside the mother's body as human beings do, and as horses and cows and sheep and pigs and cats and dogs do also. There are a few mammals that lay eggs which hatch outside the mother's body. These include the duck-mole and the spiny ant-eaters. We are all familiar, too, with the kangaroo and the wallaby and the

New York Zoological Society photograph

FIGURE 11. "Penelope," an adult female duckmole, or duckbilled platypus, about $1\frac{1}{4}$ feet long and weighing slightly over $1\frac{1}{2}$ pounds. Duckmoles lay eggs about $\frac{3}{4}$ of an inch long in a flexible white shell.

opossum: the young of these animals are born before they are sufficiently developed to suck. A foal takes eleven months to grow inside the body of a mare, but a baby kangaroo is born only five weeks after the fertilized egg-cell started to divide. So, when the baby kangaroo is born, it crawls into its mother's pouch where it is warm and protected and where it finds nipples to suck.

Thus, for all mammals, milk is the food without which the young cannot develop: no wonder that human beings find the milk of other mammals one of the most important items of diet, especially for those who are growing, for those who are old, and for those

FIGURE 12. This spiny ant-eater, about 16 inches long, lays eggs which hatch in a pouch temporarily developed.

Zoological Society of London

who are ill. Thus a cow's milk contains all the most important vitamins as well as salts and fats and sugar and protein. All these, in varying quantities, are essential to our life. But the milk of other animals also is used by men : goats' milk is of great importance in mountainous countries like Norway and Switzerland and also makes fine cheese, while one or two cheeses are made from the milk of sheep. All these animals are grass-eaters, or *herbivores*.

Young herbivores do not need to be taught very much by their parents. Calves must have milk for the first few weeks of life but it is not long before they can eat grass. Perhaps you yourself can describe the diet changes of foals, lambs, young pigs, and kids ?

But the mammals in another big group have to be *taught* how to get their food. These are the flesh-eaters or *carnivores*. Can you see which part of this word means *eater ?* Among the best known carnivores are the cat family (which includes lions, tigers, pumas, panthers, and leopards) and the wolf family (which includes dogs, jackals, hyenas, and foxes). Perhaps you can name a good many more carnivorous animals ?

The young of all carnivores have to be taught how to catch their prey, and so find food for themselves soon after they cease to be dependent on their mother's milk. Have you seen a cat teaching her kittens the first steps of lying-in-wait and of pouncing ? All wild carnivores have to learn quite a lot before they are able to leave their parents.

Animals that live by grazing can survive only if they can keep out of the way of the animals that live by killing. They must learn when very young to recognize the signs of danger. For instance, wild horses, antelopes, deer, and all the defenceless animals of similar type have to be alert to unaccustomed

sounds. Also all that live in herds have to learn to respond to the warnings of the leader.

You can probably think of many more examples showing that most animals, while beginning their life toothless on a diet of their mother's milk, have to learn a lot if they are going to grow up to be adult and live on solid food that they find for themselves. If they fail to learn the right lessons, disaster will soon overtake them.

SOME THINGS YOU MAY CARE TO DO

1. It is sometimes convenient to classify animals into carnivores, herbivores, and those that have a mixed diet. See if you can put each of the animals named below into the correct one of the groups. Then see what you know, or can find out, about the production and feeding of its young.

Seal, walrus, rat, mouse, hedgehog, bat, lemur, hippopotamus, elephant, tapir, baboon, rhinoceros, lemming, blue whale, dolphin, polar bear, camel, llama, gorilla, otter, mole, marmoset, zebra, deer.

2. If one member of the class writes for information to the National Milk Publicity Council, Melbourne House, Aldwych, London, W.C.2, and another to the British Goat Society, Diss, Norfolk, you can arrange a group talk on "Cows' milk, goats' milk and milk products."

3. In most towns nowadays, in scientifically advanced countries, all milk that might possibly carry disease is pasteurized. See if your teacher can arrange for your class to visit a milk pasteurizing plant. It may also be possible for the class to visit a dairy farm.

Question 2. **What do we know of the development of the young of Reptiles and Birds ?**

Reptiles and birds are not mammals, and are alike in laying eggs. Inside the shell of the egg the young completes its early development after leaving its mother's body. In some cases the young hatch out completely ready for free movement. Have you ever seen a little chick emerge from the eggshell in which it developed ? It is at once able to stand up. Very soon it can move to some warm spot where it can dry its downy feathers, and then it is able to run about and to find its own food, provided that it is kept warm. In the same way the young of alligators and crocodiles emerge from the egg ready to run about. Indeed there are a great number of important resemblances between birds and reptiles despite all the equally important and obvious differences.

There were reptiles on the earth long before there were any birds. The earliest fossil of a bird seems to be the remains of an animal that was something between reptile and bird, though quite different in its wing arrangement from the pterodactyls or flying reptiles. You probably know that reptiles today are only a remnant of what was once a flourishing and mighty type of animal spread in vast numbers over the whole

FIGURE 13. A newly hatched tortoise.

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FIGURE 14. A baby alligator emerging from its egg.

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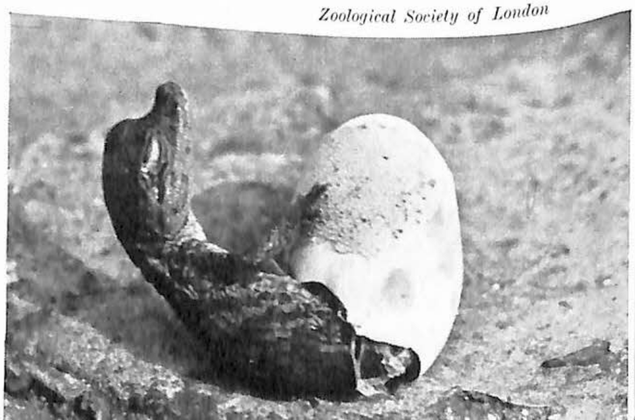


By courtesy of New Zealand High Commissioner, London

FIGURE 15. A Tuatara from New Zealand. Less than 2 feet long, it is related to giant extinct reptiles of hundreds of millions of years ago. It lays eggs.

globe, in the sea as well as on the land. Today we have only alligators, crocodiles, turtles, tortoises, lizards, snakes, and a few other rarer types. But very long ago there were reptiles that were as much as 70 or 80 feet long : we give them the name of *dinosaurs* or *Terrible Lizards.* Early types of dinosaur appeared about 100 million years ago and gradually became widespread over most of the earth. 50 million years later all the dinosaurs were extinct and only fossil bones remain to tell us some of their story. So it was a very important step in scientific knowledge when American scientists from the Natural History Museum of New York discovered fossil dinosaur eggs while searching in the sands of one of the deserts of central Asia. In this way they *proved* that these mighty

FIGURE 16. A fossil nest of 6 eggs of Dinosaur (Protoceratops)—all from 4 to $4\frac{1}{2}$ inches long. This was a fairly small Dinosaur.

The American Museum of Natural History

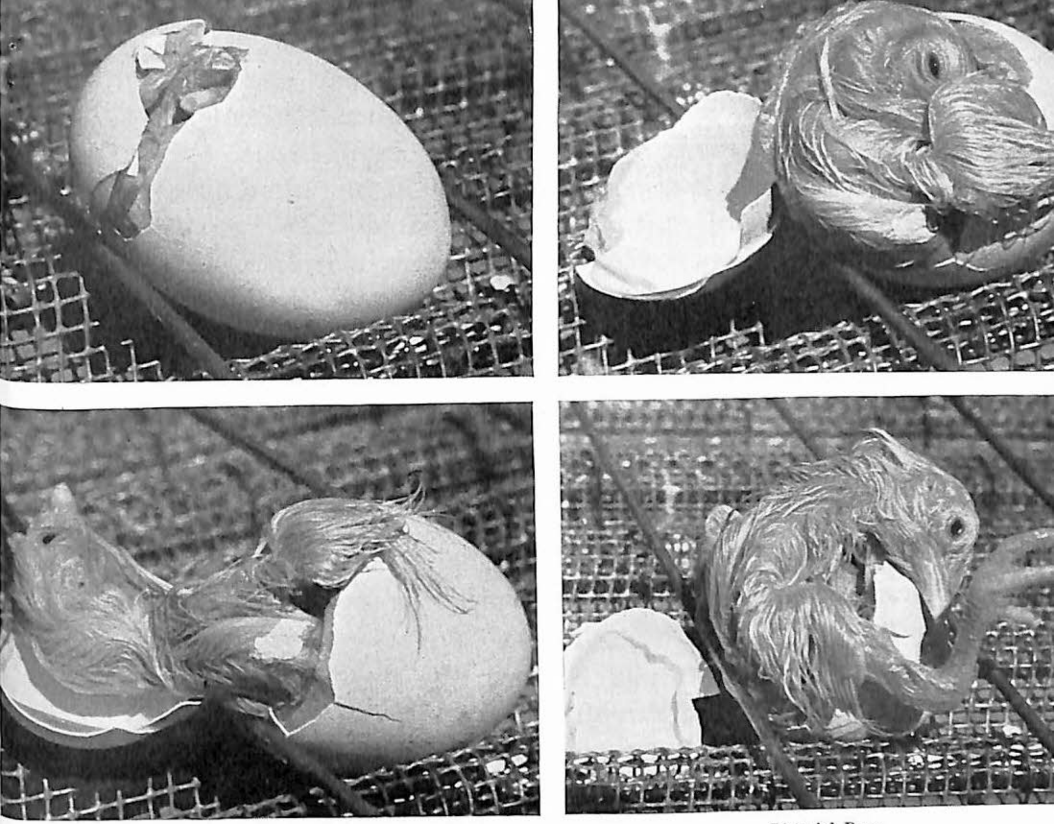
animals, extinct for 50 million years, laid eggs just like the crocodiles of today.

Eggs of birds and reptiles generally contain both yolk and white as in hens' eggs. The yolk acts as a store of rich food, though the white also is food material and is converted into the flesh and blood and bone of the developing young. The part of the *egg-cell* which we call the nucleus—from which the development commences—is very small indeed, and is to be found in a special place between the yolk and the white.

It is very easy to study the different stages of development of the eggs of the domestic hen because one can take eggs from under a broody hen after different periods of time and carefully open the shell and see how far the development of the young chick has progressed.

Do you know how many days a hen must sit on fertile eggs before they hatch? And how many days are required for hatching the eggs of geese, ducks, blackbirds, sparrows, and bluetits?

Why would it be useless for you to try to hatch the ordinary hens' eggs that you buy from the shops? If you have seen the sheds in which "batteries" of hens are kept in order to lay eggs for eating, several reasons may come to your mind. But the important one is that the eggs must be fertilized. That is, a cock must have mated with the hen before she produces her egg. One of the microscopic "sperm" cells that the cock has passed into the egg tubes of the hen must have united with the microscopic egg-cell of the hen before this cell is linked up with the yolk and the white and then covered with a shell to make what we call "the egg." You may have seen a cock mating with a hen in a farmyard. He stands on the hen's back and brings the opening at the rear of his body into contact



Pictorial Press

FIGURE 17. Four stages in the hatching of a hen's egg. Note that the down on the chick is moist at this stage.

with that of the hen and passes some of the " sperm " fluid into it. Without such action no hen's eggs are fertile. The chromosomes in the egg-cell must be joined by an equal number from a male cell before the necessary cell division and growth can begin. However long the hen sits on unfertilized eggs, they will never hatch out.

Scientists have found that if hens and a cock are kept together in a restricted space and fed only on the foods specially prepared for encouraging egg-laying, then their fertile eggs are much less hatchable than if they are kept in natural conditions with plenty of grass and fresh air and sunshine. So eggs produced for

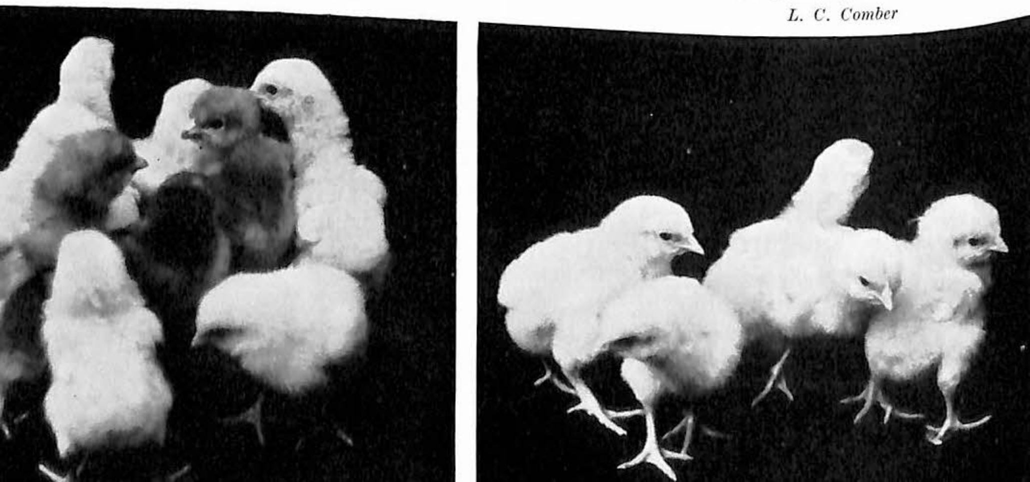
hatching come from special poultry farms and naturally they cost more. Moreover, we know that strong healthy birds can be produced only from strong healthy parent stock. So these poultry farms take great care in the selection of their cocks and hens.

The same rule holds true for the breeding of healthy and strong animals of any variety—they need to *inherit* a good constitution from two healthy parents. But not every young chick or young animal which starts off with a good constitution inherited from healthy parents necessarily grows up strong and healthy. Exposure to cold, or shortage of food, or shortage of certain essential parts of food such as vitamins or minerals, may produce a weakly animal. The same, of course, is true of young human beings. Many young people, all over the world, grow up in conditions which are unhealthy and which restrict their proper development. The conditions in which we grow up form what we call our *environment*.

We shall read more about inheritance and environment as they apply to young human beings in the later pages of this Unit. Man has learnt to control the environment of domesticated birds to a great extent. But wild birds are exposed to all the rigours of the

FIGURE 18. Sex Linkage. A Rhode Island Red cock mated with a Light Sussex hen produces day-old chicks in which the males are yellow and the females brown. But if the cock be Light Sussex and the hen Rhode Island Red, all the day-old chicks, of both sexes, are yellow.

L. C. Comber



weather and always to attack by their enemies. So the parents have to give what protection and sense of security they can to their young. Can you think of any way they do this ? Most wild birds also have to teach their young to fly : until then, they have to feed them and look after them. Some birds are fed by their parents even when they look big enough to fend for themselves. Finally, many birds are unable to stay all round the year in the climate in which they were hatched and have to migrate to places hundreds and even thousands of miles away. The country of birth would be too cold for them in winter, so for a season they must seek a more congenial climate elsewhere. But they will return again the next year and spend their breeding season in their country of birth. In some species it is probably the older birds who lead the way to the winter or summer home. But, in other species, flocks of young birds who have never been on such a migration flight set off on their own and arrive at the right spot. How they do it we do not know, but people who study birds are every year building up more knowledge which may one day help us better to understand these amazing journeys. But you will find that many things in Nature are amazing and that as we unlock one door into a secret corridor we generally find that there is another door still to be unlocked opening into another secret corridor with another door and another and another.

SOME THINGS YOU MAY CARE TO DO

1. Turn to the heading REPTILE in any good encyclopaedia. Perhaps a class group can prepare a talk on the subject. Illustrate it by making a series of large drawings that can be placed round the walls of the room for the class to study afterwards.

It would be a good thing if some members of the group dealt with extinct reptiles. You can see fossils of some of these in the British Museum of Natural History, South Kensington, London.

2. See if your teacher can arrange for some of the class to visit an egg hatchery, where young chicks are produced.

3. If you are interested in poultry-keeping, you probably know that when some varieties of poultry breeds are "crossed," all the pullets are hatched with down of one colour and all the young cockerels with down of another colour. This is said to be "sex-linked" inheritance. Prepare a talk on this subject for your class. You can obtain information from the Ministry of Agriculture, Fisheries and Food, Publications Dept., 23 Soho Square, London, W.1.

4. Other members of the class might like to read how the study of inheritance was begun on peas by a monk in the country now called Czecho-Slovakia. Look up Gregor Mendel or Mendelism in the index of a biology book or in an encyclopaedia and see if you can make a summary of what he discovered about the laws of heredity.

5. If you are reading this book at a time when birds are nesting keep a look-out for young ones learning to fly. Whatever you do, do not remove eggs from any nest you find or do anything which causes the hen to leave the eggs. (If you can think of any way of protecting the nest from such enemies as cats, you would be helpful to the parent birds!) You can get help in studying birds from the Royal Society for the Protection of Birds, 25 Eccleston Square, London, S.W.1.

6. Perhaps a group of your class can prepare a talk on MIGRATION, each member of the group dealing with a different bird. Consider particularly in every example

how the *young* take part in the migration, whether alone or with the help of other birds. The cuckoo is a very important example because of the way in which its young are fed.

7. What parts of the environment can we control in bringing up a baby ? Prepare a talk on this subject. (Hint : the environment includes food, clothing, temperature and cleanliness of the air in a room, the neighbourhood in which the home is situated, the garden if any, and contacts with other people.)

Problem B : How are some young Animals Born ? How are they Fed and Trained by their Parents ?

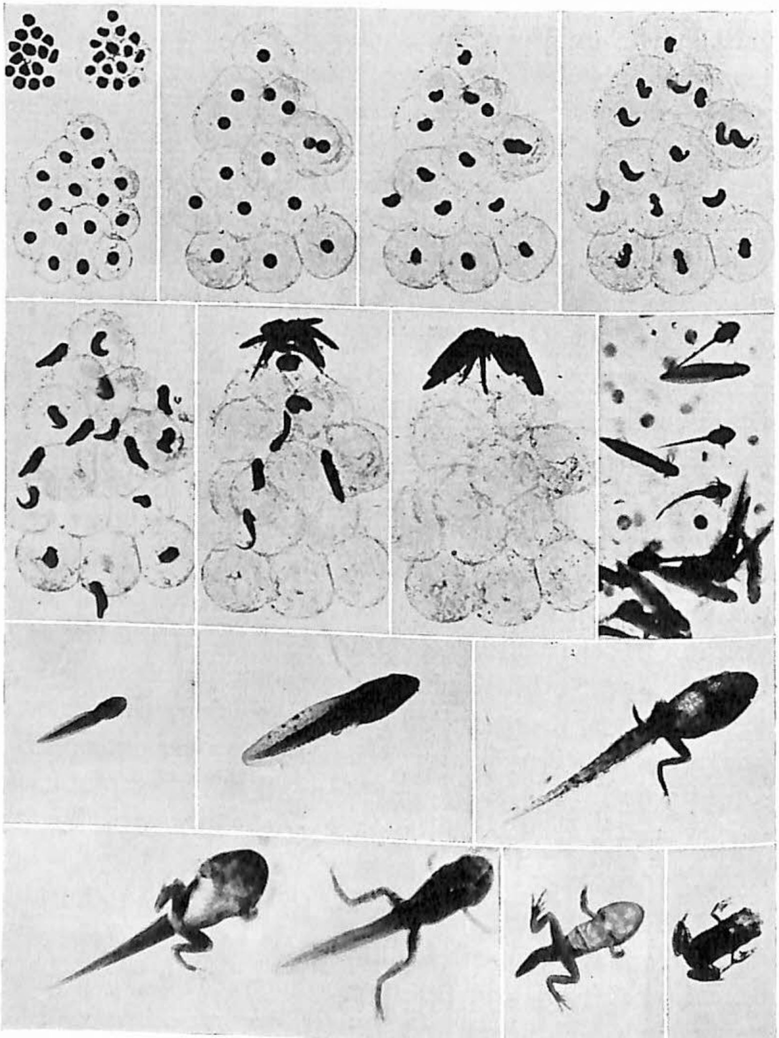
Question 3. **How are some other Animals Born and what do we know about their young ?**

We have so far considered the way of having young, i.e. of *reproduction*, in human beings and other mammals, in birds and in reptiles.

There are, however, some other animals which in shape are somewhat like reptiles but whose eggs develop neither within the mother's body, nor inside a shell, but are laid in water and hatch there. The young of these animals, when they hatch from the egg, live an aquatic life, swimming about almost as if they were fishes. But as they grow older they change and finally become land animals before they are completely adult. This group of animals are all called *amphibians*, which is a very good name because it means " both lives."

Frogs, toads and newts are three kinds of amphibians that are found in many countries. Everyone knows that frogs lay their eggs in ponds in the spring and that these hatch out into tadpoles. Many of us when younger have brought tadpoles home from a pond and have watched some of the stages of their

development. We may have managed to bring them through to the stage when they had grown hind legs but were still swimmers, or even to the stage of having four limbs and thus being very small frogs. Figure 19 shows you the stages of development of a frog.



W. B. Johnson

FIGURE 19. Various stages in the development of a frog from the egg. How many of these stages have you yourself observed?

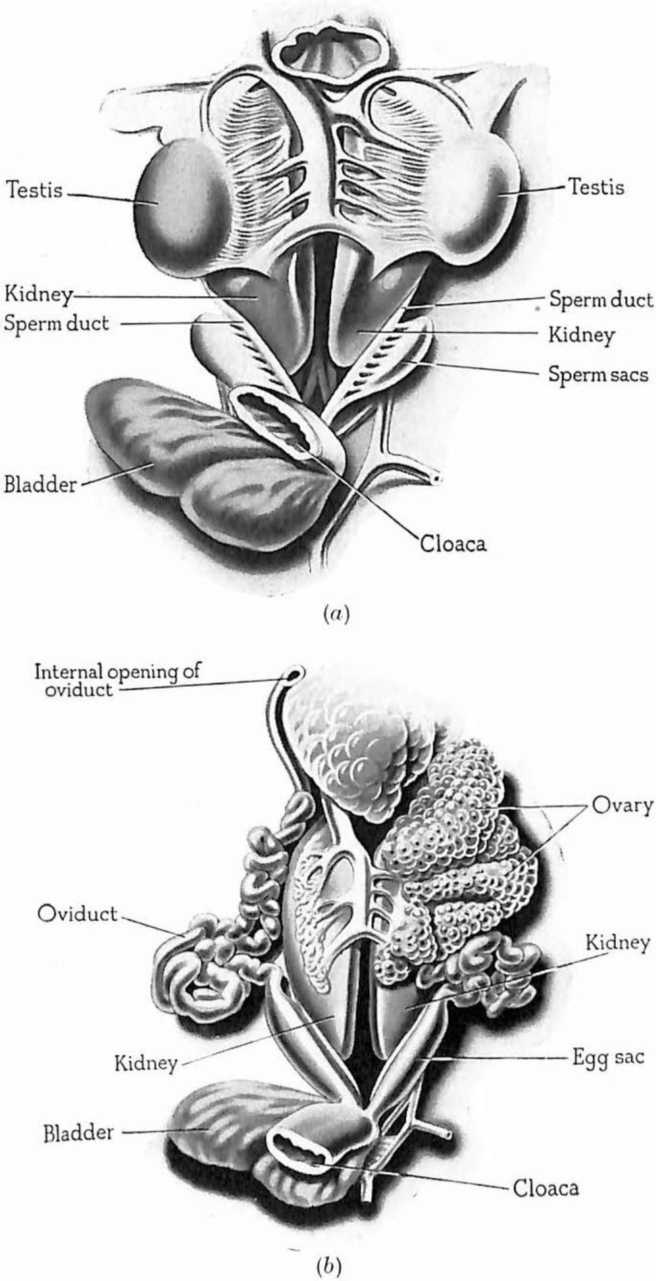


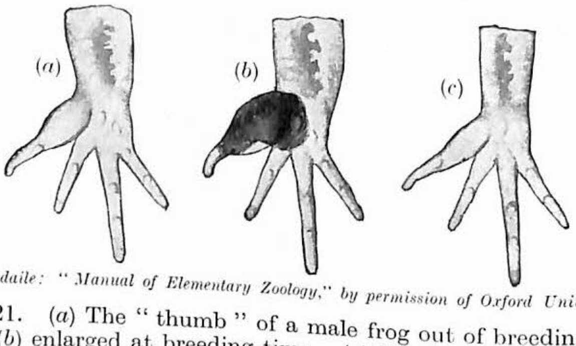
FIGURE 20. (a) A dissection of a male frog to show testes and sperm sacs. (b) A dissection of a female frog near breeding time. Note the eggs and oviducts.

Redrawn from Borradaile: "Manual of Elementary Zoology," by permission of Oxford University Press

But even the earliest stages of reproduction of the frogs are very interesting. Some of the frogs making the journey to ponds seem huge fat creatures. But they are not really fat at all. They are the female frogs completely blown out with a mass of eggs inside them and they must find water and a mate to help them get rid of this great burden within them.

Figure 20 shows you the difference in internal structure of a male and a female frog at breeding time. In the male there are two pale pinkish bodies which produce the male cells or sperms. In the female there are two large masses of eggs. The individual black eggs are big enough to be seen with the naked eye. Like hens' eggs, frogs' eggs consist mainly of yolk and other food substance, the part that will actually divide being of microscopic size.

To enable her to pass these eggs into the water, the female needs the help of a male frog. When they are both in the water the male will climb upon her back and they will swim along together, the male using only his hind legs in swimming and having his front legs clasped upon the female. At breeding time each "thumb" of the fore limb of a male frog develops a big pad, as shown in Figure 21. This serves to help him to grasp the female and to press upon her at the



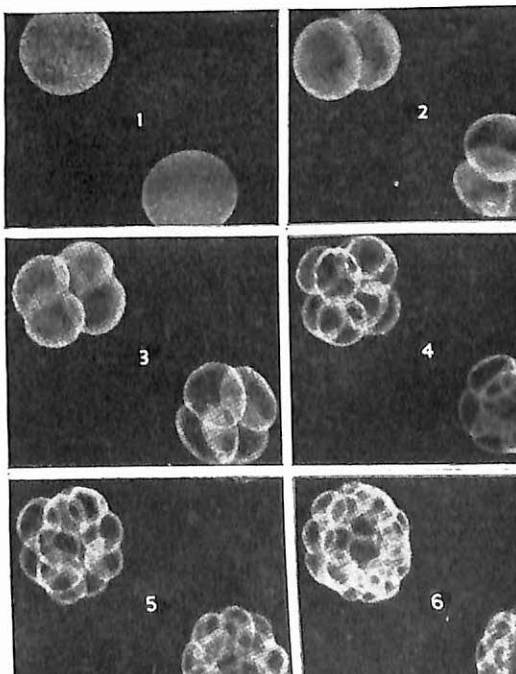
From Borradaile: "Manual of Elementary Zoology," by permission of Oxford University Press

FIGURE 21. (a) The "thumb" of a male frog out of breeding season, and (b) enlarged at breeding time. (c) The female "thumb."

time when she is ready to expel the eggs. Then at the moment this happens the male frog pours out of his own body the fluid containing the male cells or sperms. One of these tiny swimming cells makes its way through the skin of every black egg, finds its way to the egg-cell, and fertilizes it by adding its chromosomes to those of the egg-cell. So the sperm and the egg-cell become one. Before fertilization the egg-cell and the sperm each possessed only half the number of chromosomes found in the ordinary body cells of the parents. Fertilization restores the full number of chromosomes just as in the case of the human fertilized egg-cell. The fertilized egg-cell now proceeds to divide into two. Then each of these cells splits into two more and so the process goes on, as shown in Figure 22. Because the eggs of frogs develop in water and are therefore convenient to study, scientists have found out a lot about the way in which they develop. Some of the things they have discovered help us to understand the earliest stages in the development of the fertilized eggs of "higher" animals such as birds and mammals.

Other amphibians reproduce in very much the same manner as frogs, but with variations. For instance, the eggs of toads are laid in long strings instead of in the usual mass of frog spawn with which most of us are familiar, while the eggs of newts are fastened singly to water plants. In all

FIGURE 22. The earliest stages of division of two fertilized egg-cells of a sea urchin. How many cells have been formed from each egg in stage 5 ?



From H. Munro Fox: "Biology," by permission of Cambridge University Press

these cases the eggs swell greatly after they come into contact with the water, so that the mass of spawn laid by a single female frog is very soon many times larger than the body of the frog. If you look at Figure 19 you will see that it is the jelly-like outer part of the egg that has swollen most after contact with the water.

There is one last point to note about the development of young frogs : once the eggs have been fertilized the parents have no further interest in their young ones. There is no training to fly as with birds, no training to catch mice as with cats, and, still less, none of the training that human beings have to give to their children even in the most primitive tribes. So, in the animals we have considered, we have certainly gone steadily down the scale of parenthood.

SOME THINGS YOU MAY CARE TO DO

1. If the time of the year is suitable, go to your nearest pond and see what stages in the development of amphibians you can find. It will be a help if your teacher can enable you to see a film or filmstrip, for then you will know better what to look for.

2. Visit your nearest museum and see if you can find models of amphibians and of the stages of their development.

3. Ask your librarian to help you to find pictures of Mastodonsaurus and Archegosaurus, and other extinct amphibians. There are splendid fossil specimens in the British Museum of Natural History, South Kensington, London.

4. Prepare a talk for your class on the difference between frogs and toads.

Question 4. **How are young Fishes produced?**

Most of us, when we eat a fish, never wonder how old the fish was when it was caught; we are concerned only with the length of time it has been dead. Yet the fact is that many a young person eats a plaice or sole that is some years older than the eater, and may eat a piece of tunny fish or of salmon older than the eater's parents.

The way in which fishes produce their young is not the same for all. But there are certain parts of the process that are the same for most of them. For instance, the female fish generally produces masses of eggs in what we know as a "hard roe." A common plan is for eggs from the *roe* of a female fish to be shed into the water and at the same time for the male to shed *milt* or male fluid into the water nearby. The milt contains the minute sperm cells which swim to the eggs and fertilize them. Just as with the other types of animal we have considered, this means that the full number of chromosomes is made up when the

FIGURE 23. Salmon leaping a small cascade as they proceed upstream to lay their eggs.

Fox Photos

fertilization takes place. After that the fertilized egg begins to divide, and each daughter cell to divide again, and so on and so on until eventually a baby fish has been produced.

Most fishes lay an enormous number of eggs. Clearly this is necessary if the fish population is to be kept up. For not only are young fishes likely to be devoured by other fishes and by lobsters and crabs and so on, but the fertilized eggs are likely to be eaten by many fish. Herrings, for example, get their food by taking in great quantities of sea-water, filtering it through their gill rakers, and swallowing the solid material that has thus been strained from the sea.

A female turbot may lay as many as 9 million eggs in a year and yet the turbot population probably does not increase much. A female cod may lay 6 million eggs, and the sole over half a million eggs. So we have some idea of the colossal wastage involved in this sort of reproduction. Just stop to compare it in your mind with the way of reproduction in birds and reptiles, and then in mammals, and lastly in human mammals. Can you suggest why there should be all this variation ?

Generally speaking, too, fishes have no more concern for their young than most of the amphibia. But there are some astonishing exceptions. Some of you may have caught the little fish called stickleback. But you may not have realized that the father stickleback is one of the very few fishes that has any interest at all in the welfare of its young. He twines together grass stems and water weeds and glues them with a special fluid produced by his kidneys, and so he makes a sort of nest in which the young can shelter while they grow. When the young are in the nest the father stickleback himself remains on guard nearby. Another fish which takes care of its young is the fascinating little sea-horse.

FIGURE 24. This male stickleback is protecting the nest in which baby sticklebacks are growing.

Douglas Wilson

Here again it is the male—it usually *is* the male in fishes—that protects the young.

In sharks and a few other fishes the young hatch from the eggs while these are still inside the egg tube of the mother. So in these cases the sperms have to be passed by the male into the egg tubes of the female before the eggs are laid. Perhaps you have found on the seashore the "mermaids' purses" which are the capsules which cover the eggs of dogfish (a small member of the shark family) and inside which the young fish develops. It obtains its food from yolk somewhat as a developing chick inside a hen's egg obtains food from the yolk.

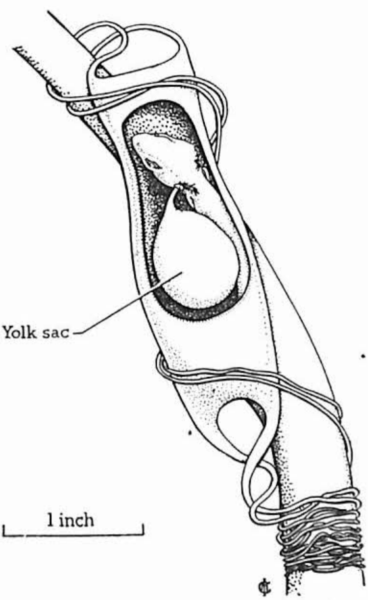


FIGURE 25. A "mermaid's purse" or egg of a dogfish, attached to seaweed, opened to show the young fish developing within.

The eggs of fish may be " sown broadcast " into the water, or they may be deposited on gravelly or other special type of ground at the bottom of the water. The eggs may float in the upper surface of the water, or, as in the case of the herring, they may sink to lower levels. Some fishes have special breeding places. For instance salmon never lay their eggs in the sea but enter river mouths and swim up the rivers to lay their eggs in quite shallow fresh water. There is a similar migration of the sturgeon, the roe of which makes the famous and expensive dish known as *caviare*.

But the most astonishing life history is that of the eel. When this fish reaches the stage of breeding, the females leave the inland ponds and the river stretches where they have been living. They start to move downstream towards the sea, passing through the rather deeper waters where the males have been living. At the mouth of the rivers they are joined by the males and then in company they swim thousands of miles across the Atlantic in a south-westerly direction to deep Atlantic waters near the West Indies. There the eggs are laid and presumably there the parents die, for they are never seen again. Instead, transparent early forms of developing eel rise to the surface and float there for three or four years in waters that are full of floating vegetation. All this time they are growing and moving towards the shores of Europe. From the open sea the young eels, or *elvers*, migrate in great numbers up the rivers at certain times of the year. The females seem to journey higher up the rivers and streams than the young males.

We have no idea how such an astonishing breeding

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FIGURE 26. An eel migrating over land.

plan, involving such prodigious journeys, ever came to be established. The American species of eel also swims to the same breeding waters. The young of the two species can be distinguished, but no one knows how they sort themselves out. If an American young eel tried to go east it would probably die before it reached the land masses of Europe, but there is no evidence that the European eel ever tries to take the shorter journey to America.

There are many other types of fish whose breeding story has been studied with much care, especially those important as sources of food, such as the herring, the cod, the pilchard, the sardine, the brisling, the tunny. But these stories are much more the sort of thing we should expect to find and not, as in the story of the eel, " stranger than fiction."

SOME THINGS YOU MAY CARE TO DO

1. If you live anywhere near a museum or zoo that has an aquarium, study the fishes that can be seen there, especially any young forms. Perhaps the keeper

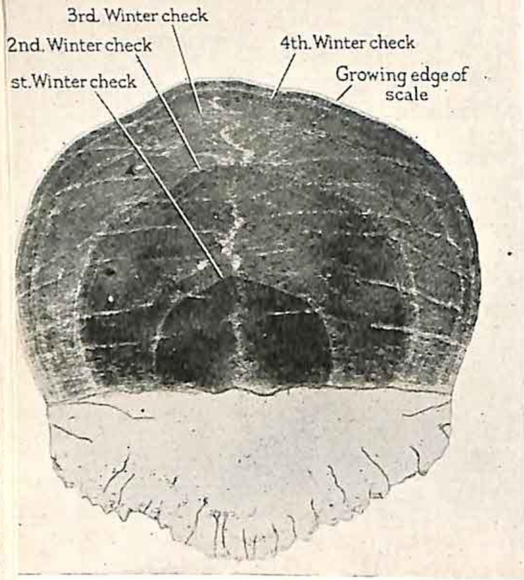

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FIGURE 27. A scale of a four-year-old herring. The check in growth every winter leaves its ring.

will tell you something about the age of some of the larger fishes.

2. If you are fortunate enough when on holiday to find yourself within reasonable distance of a fish hatchery or a marine biological station, pay it a visit. You will probably see young fish at many stages of development and you will learn more in a few hours than you could learn from a book in as many days.

3. Breed some fish at home: *Keeping an Aquarium* (Ward, Lock & Co.), *Tropical Fish and Aquaria* (Cassell) will help you.

4. Make a fish hatchery in the school, and then you can buy some trout eggs and watch the daily growth of eyes, spine, and fins. For details, write to the School Nature Study Union, 12 Grange Park Avenue, Surbiton, Surrey, and ask your teacher to borrow a copy of *School Science Review* for October 1950.

FIGURE 28. Rainbow trout, all more than 18 inches long, in a tank at Roaring River Fish Farm, Missouri.

Missouri Conservation Commission

Question 5. **How are some Invertebrate Animals Born ?**

So far, all the animals we have considered have been animals with backbones. In all of them the plan of reproduction is that the new life begins with a fertilized egg-cell. The unfertilized egg-cell and the male cell which does the fertilizing each contain only half the proper number of chromosomes, but the combining of the two cells makes up the full number and sets the process of cell division into action.

There are many types of animal without backbones. Some have a fairly hard outer case, such as lobsters, crabs, shrimps, insects, spiders, and wood lice. Then there is a different group of animals almost completely soft, like the jelly fish, sea-anemone, and earthworm. The question we may well ask is—do these animals also reproduce on much the same plan ?

We can pick out only one or two examples, bearing in mind that there are innumerable variations. Among the insects alone there is a vast number of minor differences in the story of birth and growth, and there are said to be more different species of insect than there are different species in all the other types of animals added together !

Douglas Wilson

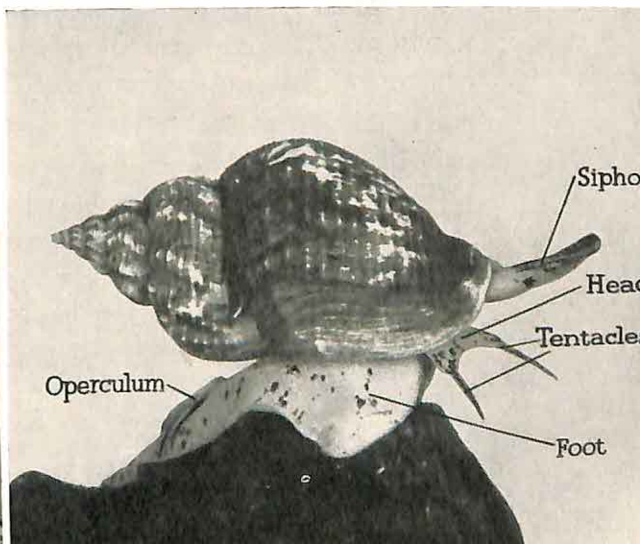
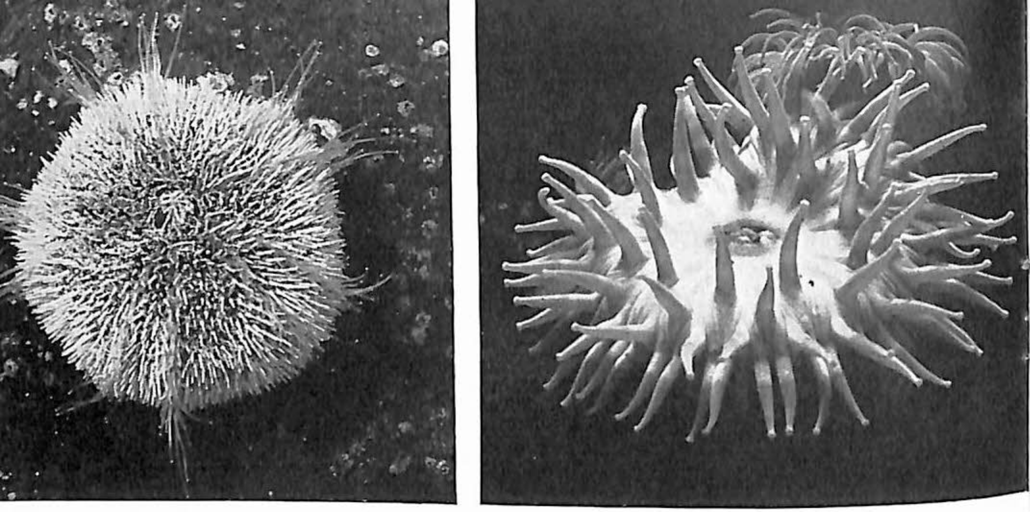


FIGURE 29 (*a*). Two invertebrates : a common octopus and a common whelk, both in act of crawling. Note the suction discs of the octopus and the names of the soft parts of the whelk.



Douglas Wilson

FIGURE 29 (b). Two more invertebrate animals: an "edible" sea urchin and a "dahlia" sea-anemone.

The lobster family. In this group the common pattern of mating is for the male to pass its sperm in a sticky liquid on to the underside of the female near the opening through which the eggs will pass. There they remain until the eggs are laid, when the sperms invade them and fertilize them.

In general the first stages of the development of the egg produce a free-living tiny rounded creature which bears little resemblance to the adult and is called a *larva*. This is a Latin word meaning "ghost." We all know that the caterpillar is the larva of a butterfly, or of a moth. Do you think that the choice of this Latin word for this early stage of a butterfly is particularly good? Anyhow, it is the word that scientists use to indicate an independent free-living form of the embryo of an animal before it has come to resemble the parent.

The larva grows and changes during a series of moults. So a relatively long time elapses before the young begins to resemble a lobster or a crab or whatever animal it has descended from. During this stage, in some cases, the mother will endeavour to protect its

young. This is notably true among crabs, some of which show well-developed intelligence.

Birth and growth among insects

It is easy for us to observe the processes of reproduction among insects, for in most climates they are all around us, often far too much so. Also we need to prevent the reproduction, as far as we can, of many types of insect harmful to man, either directly by giving him disease or indirectly by destroying his animals and his crops. Can you name three insects of each of these types ?

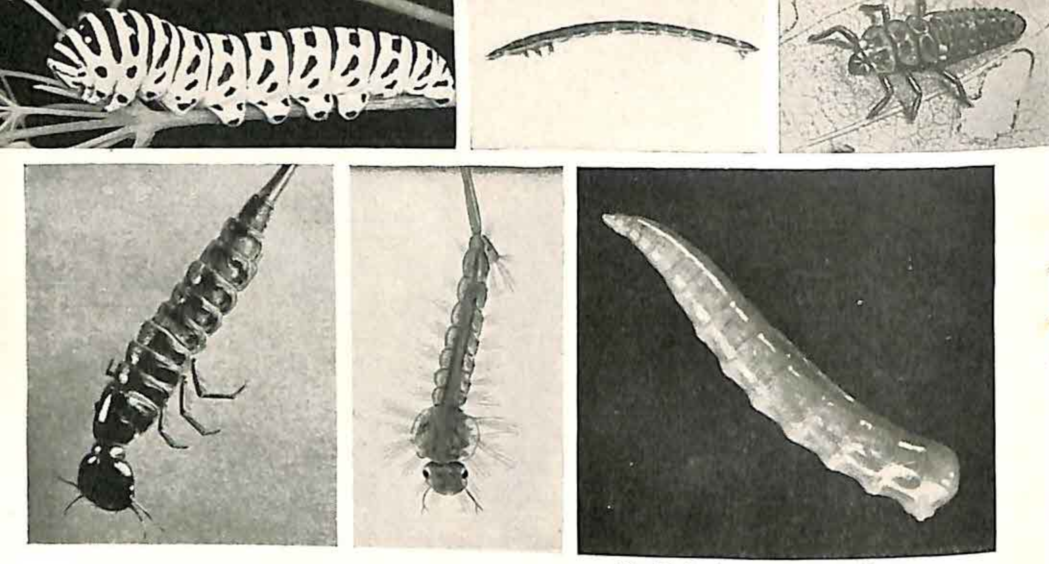
Insects mate in a variety of ways but in general the effect is the same, namely the male sperms are passed into the body of the female. You may often see two houseflies or butterflies together in the act of mating.

The fertilized eggs of an insect may be laid on a leaf (e.g. those of the cabbage butterfly), passed into the soil (e.g. those of the daddy-long-legs or crane fly), laid in water (can you name a case ?), laid on the body of a dead animal or in meat (bluebottle), laid in a pile of manure or in animal excrement of any kind (can you name an example ?), or laid under the bark of a tree (bark-beetle) or inside the body of another insect (ichneumon) or in a specially built nest (can you name a case ?).

From the egg there develops the larva, which may be a caterpillar eating leaves or a maggot living on meat. (Do you remember how fly maggots "eat" their food ?) Or the larva may be a free-swimming creature with great skill in diving rapidly (can you

FIGURE 30. Swallow-tail butterflies mating.

Wilfred Lee



Harold Bastin and L. Hugh Newman

FIGURE 31. Various Larvae.

Swallow-tail caterpillar — Wireworm — Ladybird
Waterbeetle — Culex mosquito — House fly

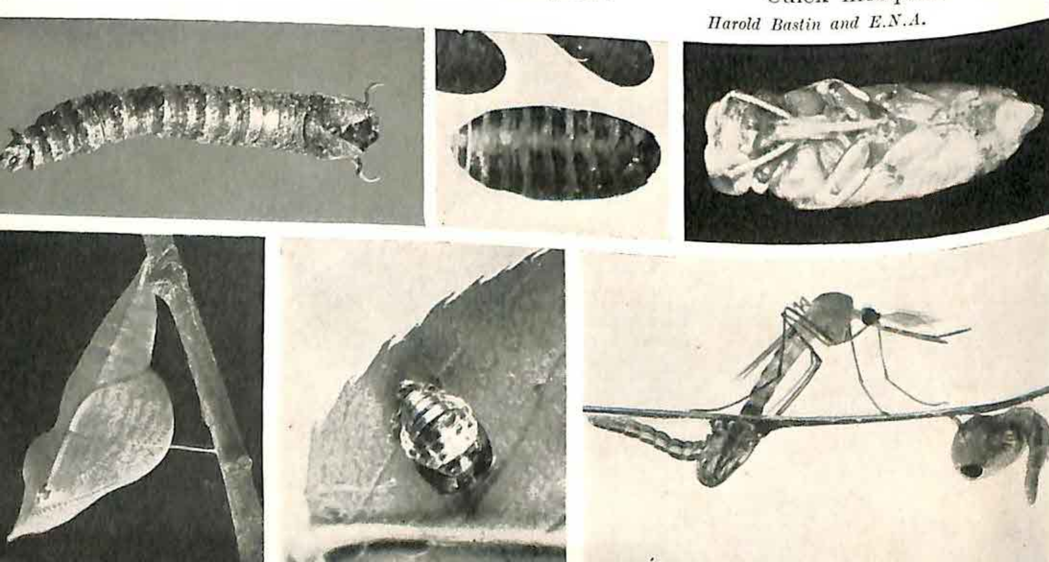
name such a case ?). It may also be a " blood worm " or it may be a caddis larva. Look at Figure 31 above and see which forms you can recognize.

Generally there is another stage before the new adult appears, a resting and skin-changing stage called the *pupa*. This is a Latin word meaning a " girl " or a " puppet." Do you consider this a good name for

FIGURE 32. Various Pupae.

Crane fly — House fly — Honeybee
Brimstone butterfly — Ladybird — Culex mosquito

Harold Bastin and E.N.A.



what in butterflies and moths is called the *chrysalis* (a Greek word meaning "golden")?

Harold Bastin

FIGURE 33. Earthworms pairing.

The reproduction of earthworms

Earthworms are particularly interesting to scientists in their manner of reproduction because they produce both sperms and eggs in the same body. Yet they exchange sperms so that the eggs are fertilized by sperms from a different animal—of the same species of course. So an earthworm can be at the same time "father" to the offspring of another earthworm and "mother" to its own. But the young of earthworms require no parental care. Parenthood, if such a term can be applied to so lowly a creature as an earthworm, is confined to the act of pairing.

Earthworms come together head to tail as shown in Figure 33. Through tiny pores each passes sperms into the body of the other. The belt around the earthworm that looks like a napkin-ring is *not* a scar where two parts of a worm have joined together; it exists to provide a sticky substance that helps to hold together worms that are pairing. When the worms separate, this ring starts to form a tight elastic bladder out of which the worm subsequently wriggles, making the bladder pass forward over the front part of its body. As this happens a few eggs are passed into the bladder from the earthworm's ovary and then some of the sperms that have been received from the other worm. Fertilization takes place inside the bladder which seals itself as it slips over the front end of the

worm, and forms a *capsule* (from a Latin word which means " a little box "). In this capsule there may be from one to five fertilized eggs, but usually only one develops. This eventually forms a tiny worm which bursts the capsule and commences life in the soil. It is not easy to find worm capsules in the soil or upon it but they *can* be found. They are about one-tenth of an inch long and dark olive green in colour.

SOME THINGS YOU MAY CARE TO DO

1. Borrow from a library the book called *Animals Without Backbones* published in two volumes by Penguin Books. There you will find pictures that you will want to copy in colour into your science notebook, for they show how such animals are born and grow up.

2. Visit the nearest marine aquarium, or the seaside if you are near enough, and see if you can find the young of any sea animals that do not have backbones. If you have ever found shrimps or prawns " in berry," that is with something like a raspberry on the underside, then you have seen a female with the eggs that it has laid and that it is going to cast off at a later stage.

3. Look in the soil of your garden for leatherjackets and the larvae of various beetles. *The Observer's Book of Insects* will help you.

4. The Ministry of Agriculture, through Her Majesty's Stationery Office, publishes many cheap leaflets about the life histories of insects which are pests. These can all be obtained through a bookseller or direct from H.M.S.O., P.O. Box 569, London, S.E.1, which will also send you a free list of Ministry of Agriculture publications. Noteworthy leaflets are those on *Codling Moth* (A.L. 42), *Magpie Moth* (A.L. 65), *Wasps* (A.L. 451), *Chafer Beetles* (A.L. 235), *Colorado*

Beetle (A.L. 71), *Leatherjackets* (A.L. 179), *Lackey Moth* (A.L. 37). This Ministry also publishes a well-illustrated little book called *Beneficial Insects* which you will enjoy studying.

Problem C: HOW DO PLANTS PRODUCE NEW GENERATIONS?

We began our enquiries with human beings and then we went on to consider lower animals. We have so far seen that there is considerable variety in the ways of reproduction, but, on the whole, there also seems to be the same sort of basic plan for all animals which have two sexes. The same sort of reproduction is to be found among plants. There is an incredibly large number of different kinds of plants, ranging from giant trees that are over 2,000 years old to microscopic bacteria that exist for only a few minutes. Can it really be true that very much the same scheme as we have studied holds also for a vast variety of living organisms which are so very different from most animals in almost every way? Clearly, we had better begin, as we did with the animals, by taking first that group which today appears to be the largest and most advanced type. This is the great group which we call "the flowering plants."

Problem C: How do Plants produce New generations?

Question I. Is there Sex in Flowering Plants, and, if so, how does it work?

Most of the plants with which we are familiar are flowering plants. Indeed it is easier in some ways to name the groups that do not flower than to name the many divisions that do bear flowers. Plants that do *not* have flowers are ferns, mosses, liverworts, horse-tails, fungi, bacteria, seaweeds, and fresh-water algae

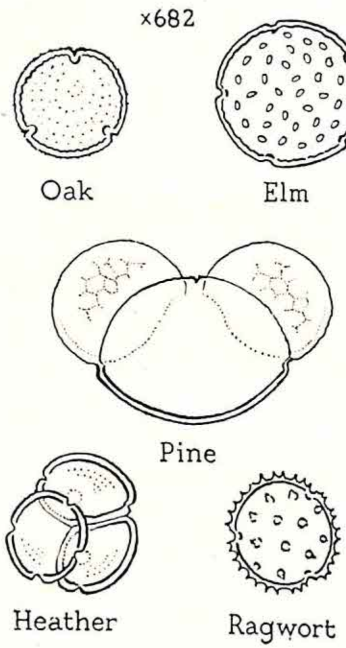


FIGURE 34. Various pollen grains. Note the "floats" on each side of the pollen grains of pine.

(the word *alga* means "seaweed"), and some other groups. We shall consider some of these under Question 2.

You doubtless know that insects carry pollen from one flower to another, or shake the pollen grains from the little sacs in which they are formed on to a part of the flower which has a sticky surface and is called the *stigma*. *Stigma* is a Greek word meaning "mark" and *pollen* comes from a Latin word meaning "fine flour." Do you think the names are suitable ones? Look at Figure 34 which shows you, magnified, five different kinds of pollen grain.

You may not realize that the pollen in a flowering plant has to play very much the same part as the sperm or male cell in an animal, and that behind the stigma lies the ovary (the same word as we use in the case of female animals) in which there wait the unfertilized *ovules* (*ovulum* is the Latin word for *little egg*). Figure 35 shows how a pollen grain, when it lands on the stigma, bursts its coat and sends out a very fine tube that grows downwards to enter the ovary. You will see in Figure 35 that the darker central part of the pollen cell—which we call nucleus—has divided and that one of the nuclei is approaching the nucleus of the ovule, just as the nucleus of a sperm cell approaches

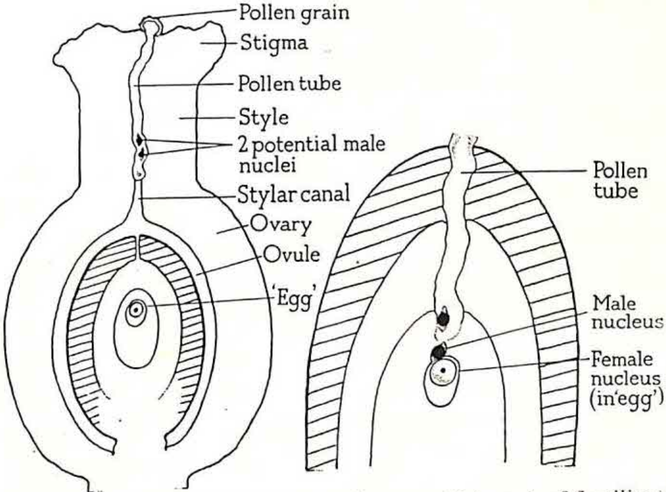


FIGURE 35. This diagram shows the essential part of fertilization in the Flowering Plants.

that of an animal egg-cell or ovum. When these two nuclei combine the essential act of fertilization is complete.

But the completion of fertilization does not mean that the seed is now formed. Indeed, just as in an animal, an *embryo* or partially-developed stage has now to be formed. In addition a supply of food for this partially-developing plant has to be made.

Figure 37 (*a*) shows a developing bean seed with the "seed leaves" attached to the young plant. Take a bean seed for yourself, open it and very carefully extract the tiny plant and put it in a pot of fine soil in a warm spot and see what happens.

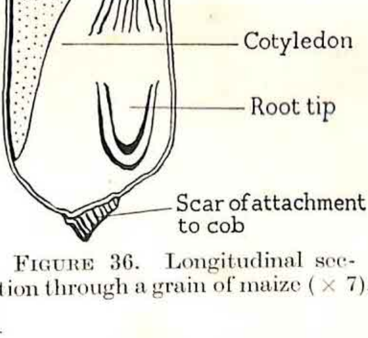


FIGURE 36. Longitudinal section through a grain of maize (× 7).

Put another bean seed which you have *not* opened into a similar pot of soil by the side of the first pot. Keep the soil of both plants moist.

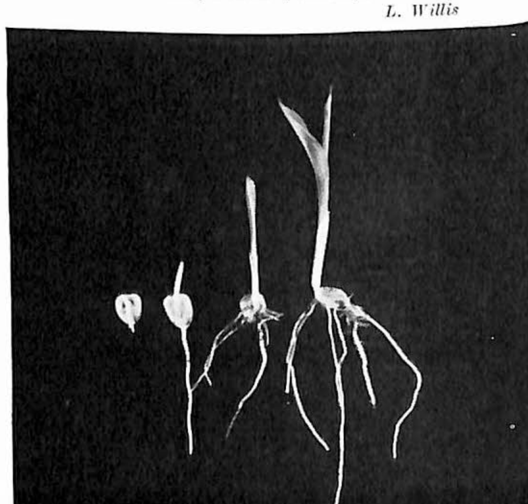
Figure 36 shows what a seed of maize looks like when we cut through it. These two Figures, 37 (*a*) and 37 (*b*), show us one of the ways in which we classify most flowering plants. Those in which the food storage is found in *two* seed leaves, as in the bean, form one group. Those in which, as in maize, wheat, oats, and the other grasses, there is only *one* seed leaf form the other group. The scientific word for seed leaf is *cotyledon,* so flowering plants are conveniently grouped into the *dicotyledons* which have two seed leaves, and the *monocotyledons* which have one seed leaf. But in the seeds of both groups we have the same basic arrangement, namely an *embryo* and a supply of food to provide for this embryo when, under suitable conditions, it starts to grow.

There is, however, one kind of flowering plant that does not fit into either of the two groups we have just named. This is the group to which fir trees and pine trees belong. In these trees there are special leaves which bear seeds, and these seed-bearing leaves are collected together to form cones. So this group is called *conifers* or " cone-bearers."

GURE 37 (*a*). Seedlings of a dicotyledon (a bean).

FIGURE 37 (*b*). Seedlings of a monocotyledon (maize).

L. Willis



SOME THINGS YOU MAY CARE TO DO

1. If it is summer time and you have a pocket lens, shake pollen grains from different flowers on to a piece of white paper. Examine them and make drawings. If you have any form of microscope, shake the pollen dust on to glass slides very thinly, and then examine under different magnifications.

2. If it is summer or early autumn, you can probably find some seeds still in formation in the ovaries of flowers. Cut through the ovaries, as shown in Figure 38, so as to find the arrangement of the ovules and the fleshy part through which the pollen tube penetrates to complete the process of fertilization.

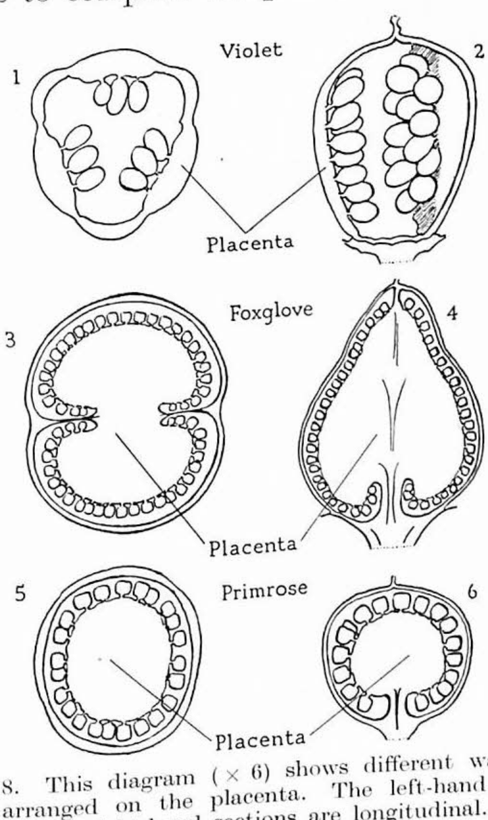


FIGURE 38. This diagram ($\times$ 6) shows different ways in which ovules are arranged on the placenta. The left-hand sections are transverse and the right-hand sections are longitudinal.

3. Prepare a talk for your class on insect pollination of flowers. Note what kinds of insects go to different flowers. Your librarian will probably help you to find suitable botany books with illustrations. Make enlarged copies of some of these for fixing on the board with scotch tape.

4. Find out from seed shops or seed catalogues something about the chemicals used to clear lawns of weeds and how they work.

5. See if your teacher can show you any films showing plant reproduction.

Problem C : How do Plants produce New generations ?

Question 2. How do plants which do not form seeds develop young ones ?

Most people know a little about the way that flowering plants form seeds. But few, even of those who have lived all their life in the country, can tell you how ferns and horsetails, liverworts and mosses reproduce. And this is not surprising, because without the use of the microscope they simply could not find out.

Even with the help of the microscope it is extremely difficult to trace the process of birth and early growth. So all these members of the plant kingdom, together with the seaweeds and the fresh-water algae, with fungi and bacteria, are often classed together as *Cryptogams*. The Greek work *kryptos* means " hidden " and the word *gamos* means " marriage." Is the word cryptogam a suitable one for these plants ?

We cannot here describe in detail the reproduction process for all these different groups of cryptogams, so let us take as examples one fern and one fresh-water alga and then, in a separate answer, the bacteria.

All of these plants, except the fungi and bacteria, are said to be *green* plants because they contain the sub-

stance chlorophyll (see Unit 4, page 45) which enables plants to take up energy from the sun and build up starch, sugars, oils, and proteins from the simpler substances that they absorb.

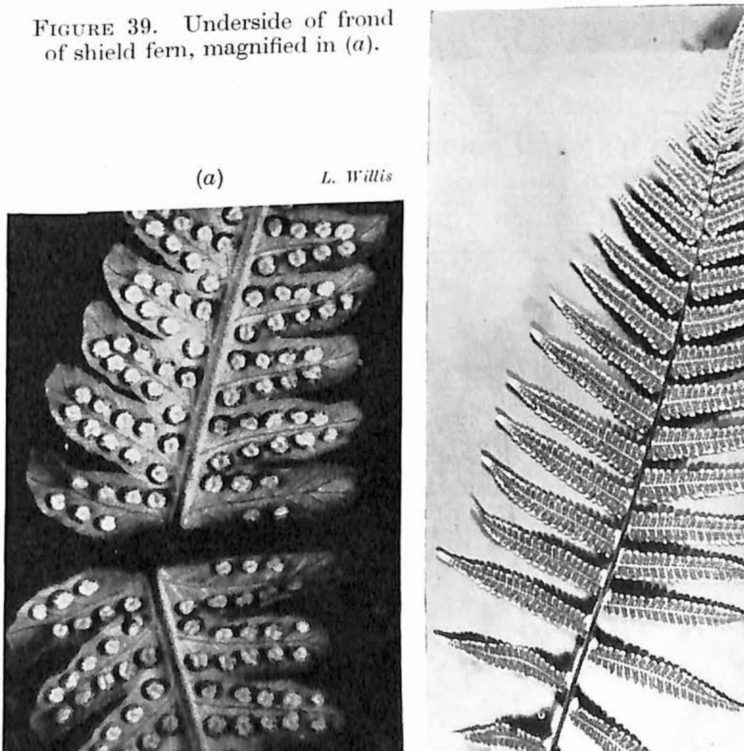
The reproduction process in ferns

In English woods and hedgerows a very common fern is the shield fern. The green part other than the stem is usually called a *frond* to distinguish it from the leaf of a flowering plant. If you look on the underside of the fronds about midsummer you may see small brown patches. Each of these is called a *sorus*, from a Greek word meaning a "heap." These "heaps" consist of little bags of *spores* protected by a shield which shrivels when the spores are ready to be shed. Now *spore* comes from a Greek word meaning "seed." Spores are very very small and consist of only one cell. They are therefore completely different from ordinary plant seeds which consist of very many

FIGURE 39. Underside of frond of shield fern, magnified in (*a*).

(*a*) *L. Willis*

(*b*)



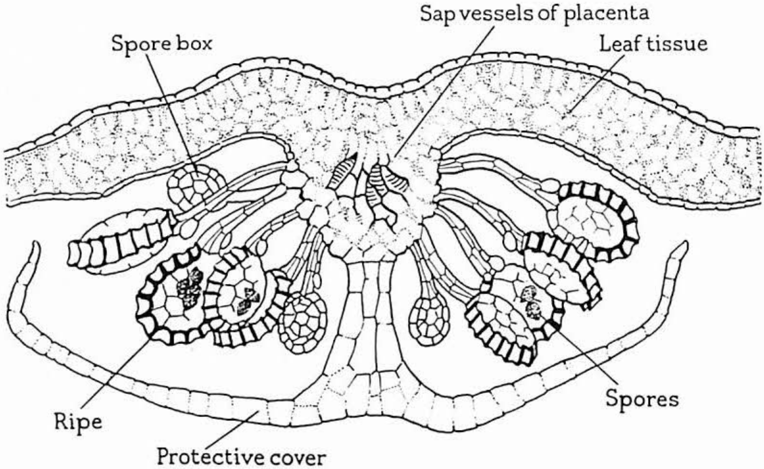


FIGURE 40. A section (× 70) through a fern frond to show the structure of a sorus.

cells indeed and contain not only food cells but a partially-developed plant.

When the spores fall to the ground in a suitable damp place they burst and develop a root hair on one side and a thread of cells on the other as shown in Figure 41. A sort of heart-shaped plate, with two lobes at one end, gets formed: this is called a *prothallus*. This word is made up from two Greek words: *pro* which means "before," and *thallos* which means a "young shoot." As you will realize it is necessary to invent a special name for such a growth: it is not a young fern, nor is it a spore. Do you consider the name prothallus a sensible one?

This tiny green structure, consisting of a relatively small number of cells, is not more than a quarter of an inch in length. Except in the middle, where it is several layers thick and forms the *cushion*, it is only one cell thick. It takes some weeks to develop to this stage. Then, on the underside of the cushion, two types of cells develop. Some of these cells are going to make egg-cells, and some are destined to become male

cells. Eventually the egg-cells are ready for fertilization, and the male or sperm cells are released. The sperms have the shape of a spiral coil and make their way forward in moisture by a rotating movement, until they find the egg-cells and fertilize them. From the fertilized egg-cells a new growth gradually takes place and *this* is the young fern, as shown in Figure 41 (3).

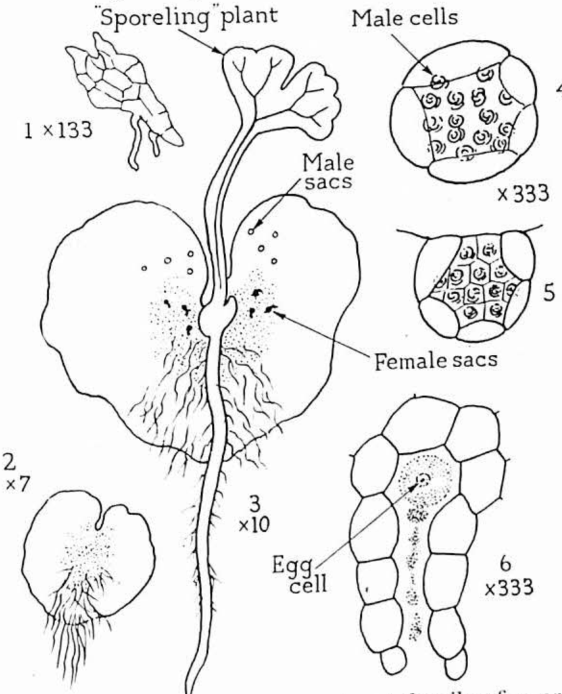


FIGURE 41. A diagram to show structural details of a prothallus.

Hundreds of millions of years ago, when the Coal Measures were being laid down (see Unit 3), plants very much like ferns (though they were *not* ferns) were common and grew to giant size. There were no flowering plants at that time.

Other cryptogams

Having discovered how ferns reproduce, and how difficult it is for the untrained person to find the

various stages, we are probably not surprised that most people know very little about the reproduction of the other cryptogams. In Figure 42 you can see pictures of various stages of reproduction in a moss and a liverwort. If you want to learn more about these you can find all the information in a good botany book.

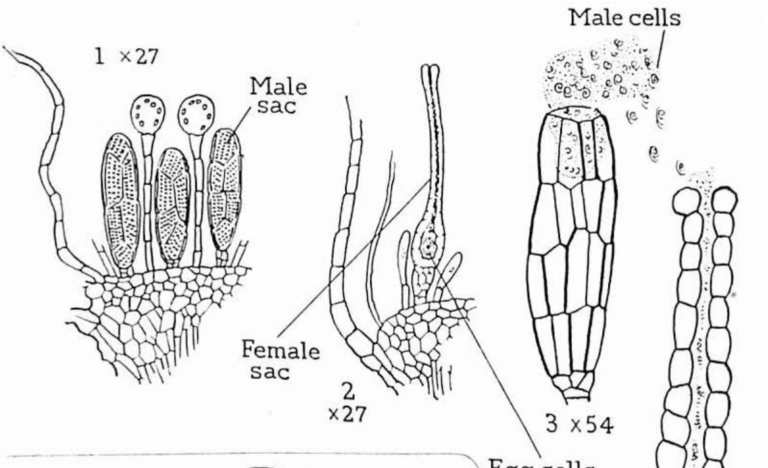


FIGURE 42. How sex cells form and unite in moss (1–4) and liverwort (5–7).

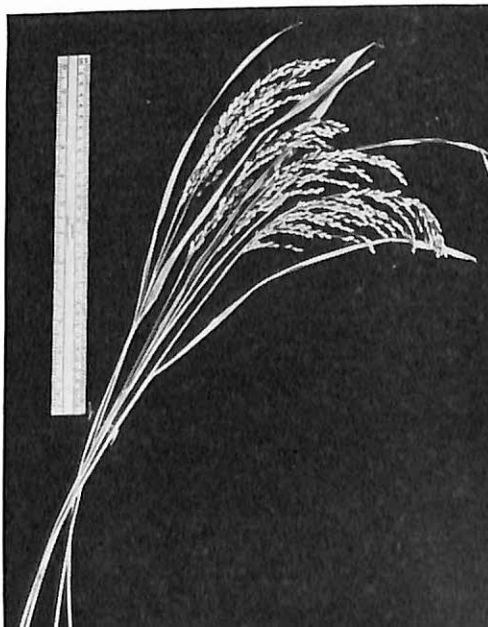
How these plants reproduce

No doubt you will consider that what you have just been reading about the reproduction of cryptogams is rather complicated. Certainly it is a great advantage to man that the plants which are important for his food are all flowering plants, so that by transferring pollen from one flower to another he has been able to "cross-fertilize," as we say. By this means men have produced, and continue to produce, new varieties of apples, pears, plums, potatoes, tomatoes, and, even more important, new varieties of the cultivated flowering grasses—wheat, maize, barley, oats, and rye. In warm climates man has produced important varieties of rice (e.g. Nahda), the chief cereal for hundreds of millions of people. If wheat and rice had reproduced in the same way as ferns it would have been very much more difficult to attempt to breed new strains. Can you think how one would start to cross two different ferns ?

It is also of interest that the flowering plants appeared much later than the cryptogams in the geological history of the earth. Indeed the club-mosses and horsetails of today may be regarded as just a few rather insignificant remaining forms of what were once mighty plants spread widely over the surface of the earth. At the time of the tropical jungles from which the Coal Measures were formed horsetails grew as great trees forty or fifty feet high and club-mosses could be as much as ten feet high.

FIGURE 42 (*a*). The wonderful new ric
Nahda.

By courtesy of F.A.O.



A good pocket lens and a microscope are necessary if you are to study the reproduction of ferns, mosses, and liverworts. In addition, you will need special guidance with plenty of detail, so it is best for you to get aid in this from suitable books on botany. Your librarian will help you.

The following are some of the things you can do without a microscope.

1. During the summer make a collection of different types of fern frond, especially some with sori. Make coloured drawings of these and paste them in your science notebooks. Search damp soil in woods or gardens where ferns are growing, and see if you can find prothalli with young fern plants growing from them as in Figure 41.

2. Collect specimens of moss and learn to recognize some common kinds. Make coloured drawings of them and paste them in your science notebook. You can also press and mount some named specimens, though most mosses are best preserved in small envelopes. Try particularly to find and to draw, using your pocket lens, some capsules of mosses.

3. Look for a patch of horsetails and collect specimens. Examine them thoroughly, pulling them apart and using your pocket lens. Make drawings, enlarged if possible. Record carefully the spot where they grow and, in the following March and April, go to look for fertile shoots.

4. Go to your nearest museum and ask the curator to show you where to find the fossils of Coal Measure plants. He will almost certainly have examples of horsetails, and perhaps also of ferns and club-mosses.

Algae and how they reproduce

The name *alga* is given to plants which are specially adapted to life in water, whether salt or fresh, and which contain chlorophyll (see Unit 4). Can you recall what chlorophyll does ?

Spirogyra. You probably know something about this alga already, for it is very common in ponds in the

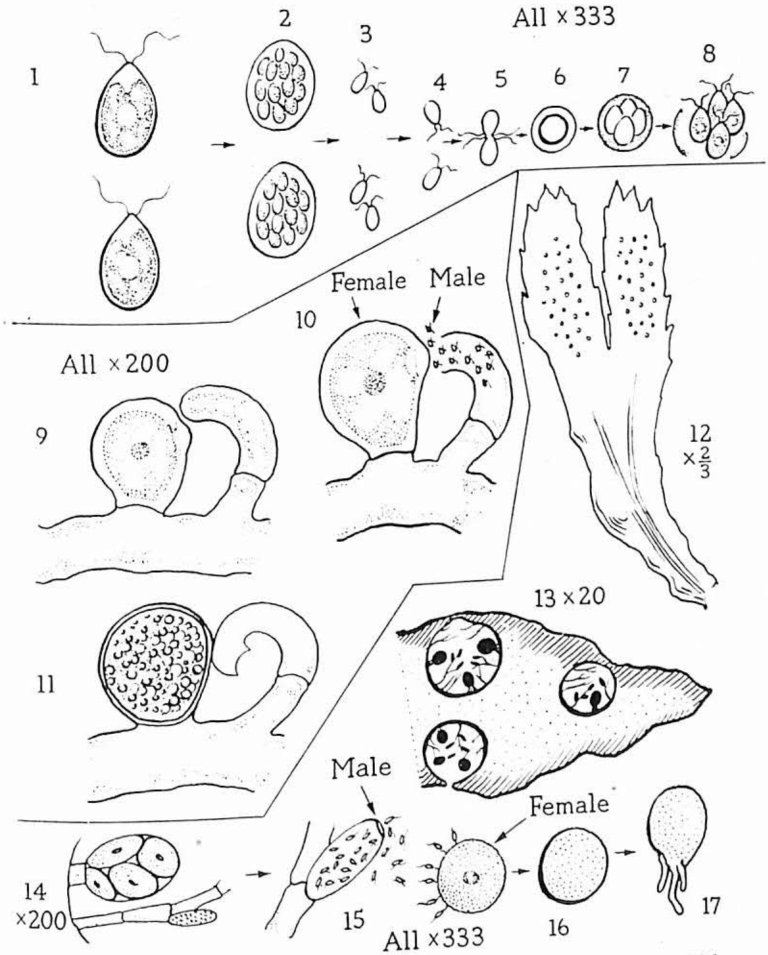


FIGURE 43. How sex cells form and unite in Algae. 1–8 Chlamydomonas. 9–11 Vaucheria. 12–17 Seaweed Fucus.

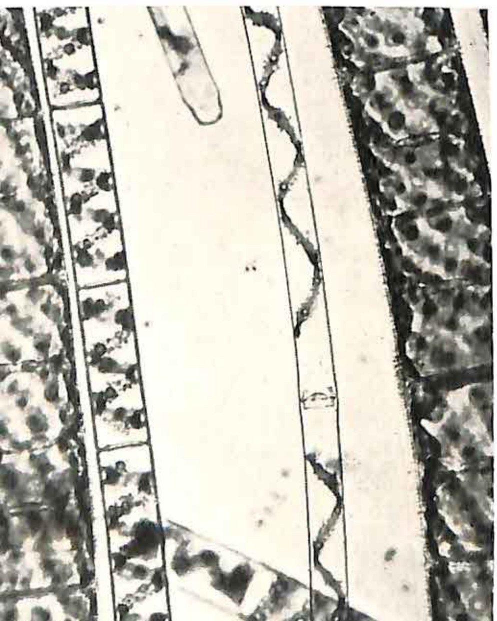
British Isles and is both interesting and beautiful. You may already have seen some of this alga under the microscope. If so you will already be familiar with the spiral band chloroplasts such as those shown in Figure 44. Here you see different kinds, or species, of this alga.

Most of the time it grows by ordinary multiplication of cells and in early summer can be found in bright green masses of fine threads which may be several feet across, floating on the surface of ponds and ditches. The threads are slimy to the touch and this helps to identify the alga before we examine it beneath a microscope. By careful focusing we can see the spiral band, or even bands, of chloroplast near the surface of the cells. We may also be able to locate the nucleus suspended by " bridles " of cell material. The word *cytoplasm* which is sometimes used, and which sounds very impressive, merely means *material in the cell.*

What is particularly interesting to us at this stage is that Spirogyra does not always reproduce by mere splitting followed by breaking of the threads and by lengths floating away to form new colonies. At certain times some of the threads come to lie parallel to one another and then all the cells of these threads turn themselves into gametes or marrying cells.

FIGURE 44. Three different species of Spirogyra (× 100). Note the gem-like centres around which starch is formed.

Flatters and Garnett Ltd



Look at Figure 45. Here you will see that, with one or two exceptions, all

the cell material of every cell in the left-hand thread has passed into the corresponding cell of the right-hand thread and has joined with it. Various forms of this combining of cells take place in different species of Spirogyra. In this form you will see that a ladder arrangement results from the "bridges" which are made between one cell and its opposite number. In (3) of Figure 45 you see the cell matter of one cell passing across the bridge.

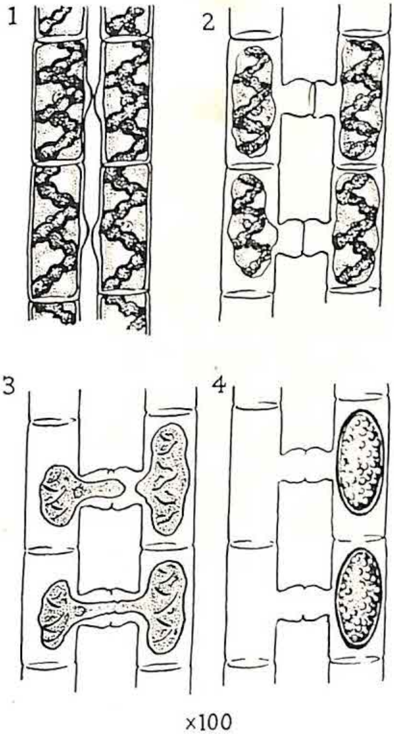


FIGURE 45. Reproduction by paired chains of cells in alga Spirogyra. On left potential male, on right female chain. In 4 the thick-walled resting stage is seen.

In (4) of Figure 45 you see that the cell materials of the pairs of connected cells have joined together, so that every left-hand cell becomes an empty box. Because in other forms of reproduction the cell that moves most is the male cell, botanists usually regard the cell that empties itself as having been the male cell and vice versa. But in this case there is no difference in size between the male cell and female cell. In fact we are not able to find any difference at all between one or other partner of the cells that join together. But we have to recognize that through most forms of living organism there runs this "urge," as it were, of certain cells to fuse together.

The thick-walled cell shown in (4) of Figure 45 can

later, when in a suitable spot, burst its thick wall and start a new colony. Perhaps it possesses renewed vigour. Can you think of any other advantage for the spreading of Spirogyra which might result from the formation of these fused cells with thick walls ?

SOME THINGS YOU MAY CARE TO DO

1. If you spend a holiday at the seaside you will probably want not merely to make a collection of different kinds of seaweed, but also to know something about them. Here are the names of some books that will help you in this.

Very simple book : *Life on the Sea Shore* (Oxford).

Books with more detail : *The Sea Shore* (Collins), *British Seaweeds* (British Museum), "*The Observer*" series.

2. Before you start yourself to collect Spirogyra and to look at it under the microscope, you would know better what to look for if you could see a filmstrip which shows you details of cell structure in several species and also the reproductive processes.

Problem C : How do Plants produce New generations ?

Question 3. **How do the Very Simplest Plants Reproduce ?**

There must be very few people in those parts of the world where wheat is a staple crop who do not eat bread at least once a day. Probably very few of them have ever looked at that microscopic plant which enables "leavened" bread to be made. Can you yourself say what this plant is and how it works ?

Figure 46 shows you a very high magnification of another plant of the same family—a yeast. This one is brewer's yeast, used in making beer. But there are thousands of kinds of yeast : they live in the "slime-fluxes" formed where branches have been cut from

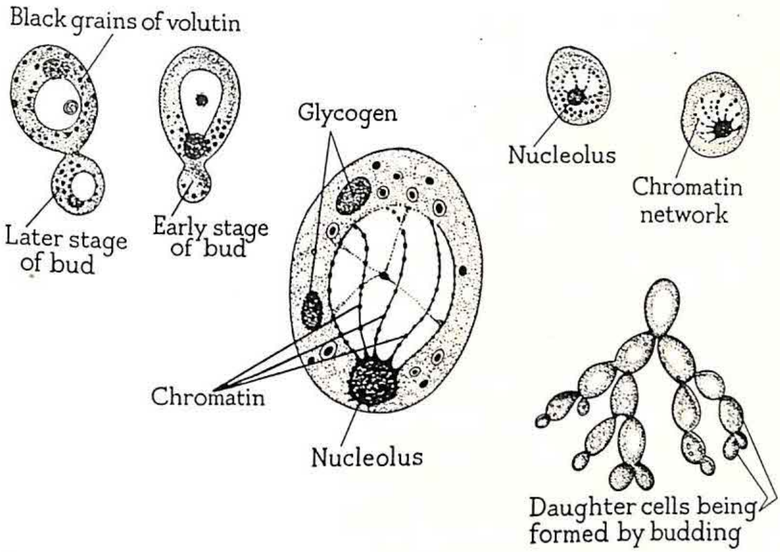


FIGURE 46. Diagram showing the structure and budding of yeast cells.

trees; they live in the soil on the broken skins of over-ripe fruit and in many places where things ferment. They are used in making most alcoholic drinks including cider and wine.

Brewer's yeast was given the name *Saccharomyces* from Greek words meaning "sugar" and "fungus." This name tells us something about brewer's yeast; it tells us that it does something with sugar. What it does, under suitable conditions, is to turn a solution of sugar into a solution of alcohol.

What interests us here about brewer's yeast, however, is its method of reproduction. If it is present in a solution that contains the right substances for its growth, yeast reproduces itself by rapid "budding." Look again at Figure 46 and notice what research workers have seen regarding the way in which budding shares some of all kinds of cell material between what we may call the mother cell and the daughter cell.

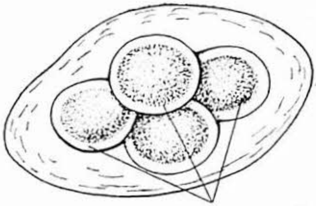


FIGURE 47. Thick-walled spores formed inside a yeast cell.

Under good conditions this daughter cell itself begins to bud before it is fully formed, so we arrive at branched chains of yeast cells joined end to end and bigger at one end than the other.

This is obviously a much simpler method of reproducing than we find in most other plants. Now look at Figure 47. Here we see how yeast cells behave when they find themselves in places which do not supply them with the food they need. In the laboratory, yeast can be made to form *spores*, like those shown, by being spread on a damp block of plaster of Paris or on the surface of a potato. Here, inside the cell wall, are four very tiny cells. When the parent cell dies and the wall collapses, the tiny spores are set free. They are so minute that they are rapidly carried away by any current of air and they are much too small to see under ordinary conditions. But things of about that size are probably seen dancing about in the air on those occasions when we see a ray of sunlight entering a darkened room through a crack. On those occasions we *can* see that the air is not "empty" but that there are thousands of minute specks dancing about and reflecting light as they move.

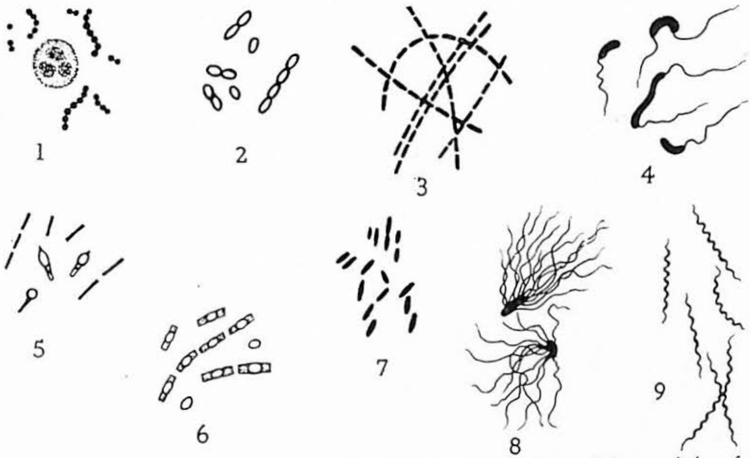
It is in this way that spores of yeast are windborne; if they fall by chance on a suitable source of food, they grow.

Bacteria. Did you know that bacteria are minute *plants*? They are extremely small and the average size of a bacterial cell is less than one ten-thousandth of an inch in diameter. You will doubtless know that they were first discovered by the great French biologist,

Pasteur, and that he had previously been doing some work on wine yeasts and such forms of fermentation.

Bacteria exist in unimaginable numbers in many of the things we can think of: in the air, in water, in many kinds of food, in the soil, in ourselves, where some of them do important work in our intestines, and so on. In fact it is difficult to devise situations in which bacteria cannot live.

What is more, many kinds of bacteria, when they find themselves in situations in which they cannot feed, form spores, just as yeast cells do. Many of the spores can exist for a very long time and then, if they find a favourable place, start to grow again. This is true of some bacteria that cause severe diseases of human beings, such as tuberculosis. Figure 48 shows you drawings of various kinds of bacteria that cause disease in man and in some other animals.



Redrawn from Godwin: "Plant Biology," by permission of Cambridge University Press

FIGURE 48. Diagrams of bacteria. 1. Streptococci from pus around a white blood corpuscle. 2. Pneumococci (which cause pneumonia). 3. Bacilli of anthrax (a terrible disease of cattle) in chains. 4. Spirilla of cholera. 5. Bacilli of tetanus (lockjaw), some forming spores. 6. Anthrax bacilli forming spores. 7. and 8. Typhoid bacilli without and with flagella. 9. Spirilla of syphilis.

You will notice that there does not appear to be any proper nucleus in a bacterium. So the material which in other types of organism is concentrated in the nucleus is presumably spread throughout the cell material in a bacterium.

Accordingly bacteria are able to reproduce by a very simple process of splitting. The cell develops a thin wall across the middle and the cell material is thus shared between two cells. These proceed to swell and to repeat the process. In favourable conditions some bacteria can double their number like this every four minutes. Suppose 100 bacteria are in a situation to reproduce in this way every four minutes. Make a rough calculation of the number that there would be at the end of an hour.

Scientists, especially those called bacteriologists and microbiologists, are interested in growing bacteria in all sorts of conditions and seeing how they behave. A simple way of growing them is in a Petri dish on a nutrient jelly. The nutrient jelly may consist of something like beef juice made firm with gelatin. The sterilized dish is kept sterile by one of several methods and to begin with the jelly is also sterile. When the scientist wishes to examine the growth of a particular bacterium, he "inoculates" the jelly with a few of the particular bacteria on the end of a needle. He then leaves them to grow. Figure 49 shows you the sort of thing that you can see after a few days, or, in certain cases, after a few hours. These

FIGURE 49. Colonies of bacteria inside a Petri dish.

Dr. R. A. Shooter

colonies of bacteria have different colours and characters that help scientists to know which bacteria they are.

It was while studying the growth of a colony of bacteria that the late Sir Alexander Fleming noticed that round a certain spot in the dish the bacteria were being dissolved by a colony formed from a spore of a mould, *Penicillium*. That is how the first *antibiotic* was discovered. These substances prevent bacteria from multiplying and destroy those with which they come into contact.

However, man's struggle against those bacteria which cause him disease is by no means over. Somehow or other some bacteria develop after a time a resistance to a given antibiotic. Then they multiply almost as readily in its presence as if it were not there at all.

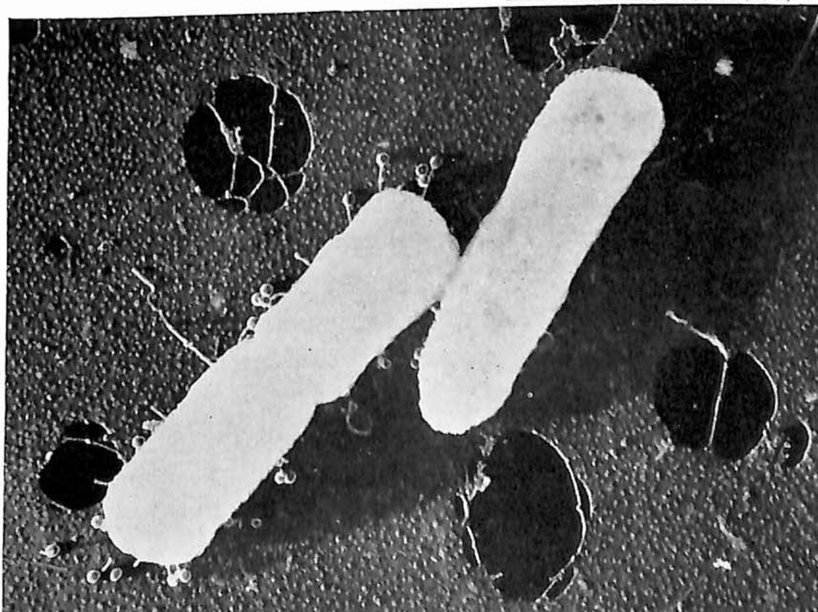
So the manner in which bacteria reproduce, and the speed with which they multiply, are still important matters to study.

SOME THINGS YOU MAY CARE TO DO

1. Take a flask, half fill it with some cane sugar solution and drop in half a thimbleful of bakers' yeast.

FIGURE 50. Electron microscope photograph of a bacterium attacked by phages (these look like short pins).

T. F. Anderson, E. L. Wollman and F. Jacob, "Ann. Inst. Pasteur," **93**, *450 (1957)*



Into the mouth of the flask insert a rubber stopper through which passes a bent glass delivery tube, of which the free end dips into clear lime water (see Figure 23 of Unit 1). Put this apparatus in a warm place. Observe and record what happens after an hour or so. Refer to Unit 1, pages 42 and 53.

2. Take (*a*) 2 level teaspoonfuls of peptone from the chemist, (*b*) half a level teaspoonful of salt, (*c*) half a cube of meat extract, and (*d*) 4 ounces of powdered gelatin and $2\frac{1}{2}$ pints of water. Heat (*a*), (*b*) and (*c*) together in the water, add (*d*) and stir till it has dissolved. Dip red litmus paper into the liquid ; if it stays red add a pinch of washing soda so that it *just* turns blue. Now strain through a coffee strainer lined with muslin and sterilize in a deep pan for 40 minutes or in a pressure cooker for 15 minutes. Pour half an inch of the liquid into a number of flat dishes (see Figure 53). The dishes should previously have been wrapped in newspaper and sterilized in a steamer or pressure cooker. Now do the following things with different dishes. Expose for 10 minutes one in the garden, one in a crowded room, one in an empty room. Breathe heavily upon a fourth. Comb your hair over another. Touch others with a dirty finger and a washed finger. Make an emulsion with material from between the teeth or under the finger-nails mixed with a little water and spread a drop or two on a dish. Cover each dish again quickly with a sterile covering and leave it in a really warm place for one or two days. Examine with a lens the colonies formed by bacteria or by spores of fungi or of yeasts.

3. Using sterile thermos flasks, cotton wool plugs and thermometers, compare and explain what happens when yeast is added to (*a*) cane sugar syrup, (*b*) distilled water.

Problem D: WHAT DO WE KNOW ABOUT HUMAN GROWTH?

In Problem A we learned something about human babies; in Problems B and C we studied how the young of animals and plants are produced. By considering many types we discovered that, for the higher plants and higher animals, there is something of a common pattern in the way that living cells behave when they are going to form new individuals. In the lowest plants, the yeasts and bacteria and similar very small organisms, we found that reproduction occurs by the simpler system of cells just splitting into two.

In the bodies of these simple plants and animals all the cells are cells of the *same* sort, so they can grow by simple multiplication. But what we often call the "higher" plants and animals are much more complex. In their bodies there are not only many more cells, but many *different* kinds of cell. (See Unit 4, page 14.)

All these different kinds of cell, in some amazing way, develop from the microscopic fertilized ovum. Different types of cell branch off, as it were, at different stages of development of the embryo; thus the kind of cells that form the human eyes are multiplying when the embryo is two to three months old.

Some kinds of cell, indeed, do not multiply until some months after the birth of a baby. Can you think of one group of cells which often gives trouble to both baby and parents? It may surprise you to know that the cells which are going to form a child's permanent teeth, as well as those which are going to form the milk teeth, have already come into being in the right positions before the baby is born!

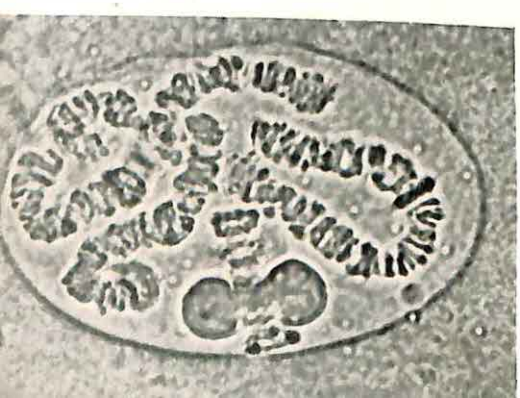
Have you finished growing all your teeth yet? Many people do not grow their wisdom teeth till the age of 17 or later; and some never grow them at all.

Question 1. **How do Cells Multiply ?**

An embryo, then, does not develop into a man by just swelling in size. Growth consists in the multiplication of cells by splitting and by the coming into being of many different types of cell with different jobs to do in accordance with a given plan and not independently of the others. They are rather like the instruments of an orchestra, all of which have to fit in with the pattern of playing laid down by the composer. Just try to think what the music might be if every player, in an orchestra of instruments of 15 kinds, played what he liked and how he liked. In the human body there are far more than 15 different kinds of cell. In Question 2 we shall consider how this orchestra of cells is conducted.

For the moment, however, we must give our attention to the general pattern by which any type of cell multiplies its own kind. Figure 51 shows how the nucleus of a living cell contains material which we call *chromatin* because it is able to take up certain dyes. When a cell is going to divide the chromatin forms the rods which we have already learned (page 11) are called *chromosomes*. But in this action (unlike the formation of marrying cells) each rod is double, being made of two parallel rods. In the centre of Figure 52 you see the dark little chromosomes facing each other in pairs between the two star-like bodies ; half of each double rod is being drawn away before a new cell wall is formed between the two stars.

FIGURE 51. The nucleus of a living cell from a Harlequin fly. This shows bands across the large chromosomes.

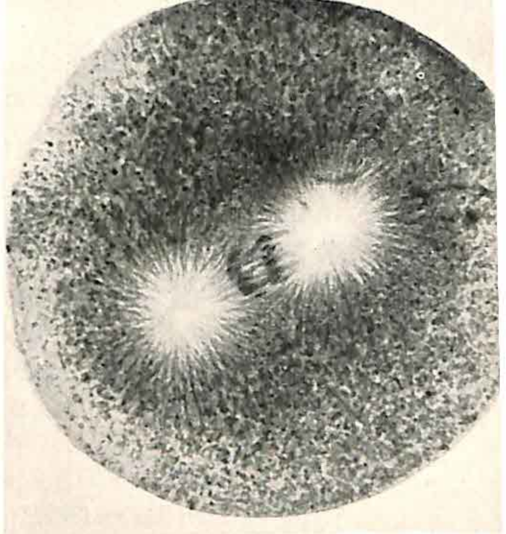


When we think about *how* cells divide we immediately realize that, unless they are somehow supplied

Reproduced from "The Handling of Chromosomes," by C. D. Darlington and L. F. La Cour, published by G. Allen & Unwin Ltd.

with food, multiplication can only produce a larger number of smaller cells. Without food there would be no increase in total size, or "growth," as we usually call the process.

But of course cells are fed. They take their food from nutrient solution through the sort of skin that exists around the jelly-like living substance. You may yourself have carried out an experiment with a nutrient solution when using Unit 5, HEALTH. If not, you can look up page 16 of that unit.



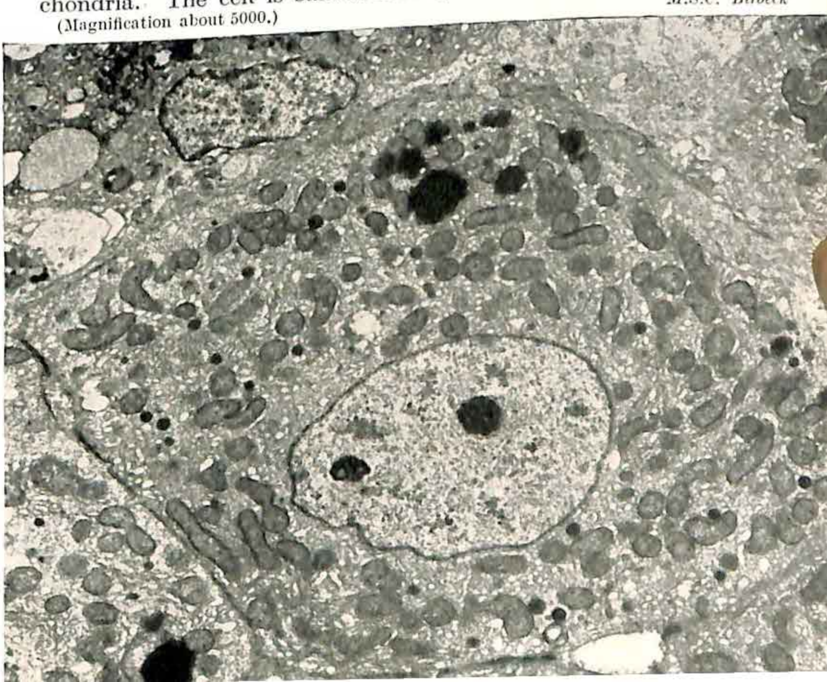
Michael Swan

FIGURE 52. An egg of sea urchin in division. A stage of mitotic division showing chromosomes.

But cells are very complicated affairs as we now know, thanks to the enormous magnification given by the electron microscope (see Figure 53).

FIGURE 53. Electron microscope photograph of a liver cell of rat. The large central oval is the nucleus; the two dark spots within the oval are nucleoli. The numerous small grey bodies are called mitochondria. The cell is surrounded by other liver cells. (Magnification about 5000.)

M.S.C. Birbeck



Just as a nutrient solution gives living cells a bath in liquid food, so it is with many of the dividing cells of a healthy human body. They are, in effect, bathed in a liquid called *lymph* that passes through the walls of the smaller blood vessels and conveys the nutrients. You already know from Unit 5 (pages 34 and 35) that blood consists of red corpuscles and many kinds of white corpuscles in a straw-coloured liquid called blood plasma. It is from this liquid that the lymph is derived.

We know that the red blood corpuscles carry the oxygen necessary for the life of the cell and also carry away the carbon dioxide the cell produces. Some of the white cells have large nuclei of irregular shape: these are the *phagocytes* or "eating cells" that engulf and destroy bacteria and other invading bodies.

SOME THINGS YOU MAY CARE TO DO

1. If you can use a microscope you can spend fascinating hours looking at and drawing sketches of microscopic slides showing animal (or plant) cells of different kinds.

If no microscope is available for your personal use perhaps your teacher can project on to the ceiling or the wall with a micro-projector.

2. The stages of normal cell division are often very wonderfully displayed in microscopic sections of growing points of certain plants. The tip of a root of an onion is very good in this respect. As very good microscopic slides of this need high-power magnification and are also rather expensive, perhaps your teacher will want to project such slides rather than lend them to individuals.

Question 2. **How do we Convert Food into our own flesh ?**

Now we must consider *how* the food we eat finds its way into the blood plasma. How is it converted into the right condition to feed the cells of our body and be built into our flesh and blood and bone? In other words we want to know what digestion *does* to the food we eat.

DIGESTION

Everyone knows that digestion starts in the mouth. The teeth tear and crush and grind the food into fine particles that are made into a paste by the *saliva*. This is a special liquid produced in glands (see Figure 54) in the cheek and under the tongue. Besides helping to make a mouthful of dry food swallowable, saliva contains a chemical substance called an *enzyme*, from the Greek word meaning " yeast." You have already experimented with brewer's yeast and found that it turns sugar into alcohol.

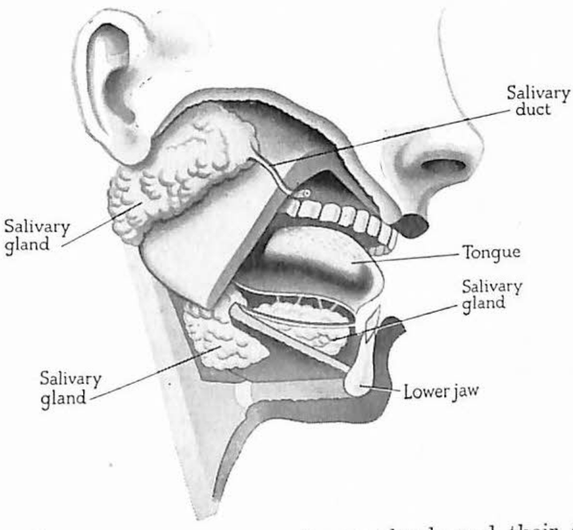


FIGURE 54. Diagram to show salivary glands and their ducts.

The enzyme produced by the salivary glands does not convert sugar into alcohol, but it changes starch into sugar. Starch is a carbohydrate, like sugar (see Unit 4), but it differs from sugar in not dissolving in water. Sugar does dissolve in water and so can be taken into the blood. Getting food substances into the blood is the whole purpose of digestion, so the saliva starts the process by changing insoluble starch into soluble sugar. All multiplication of cells is, of course, dependent upon supplies of food conveyed to the cells by the blood. And, actually, almost every cell of our bodies is continually being replaced by a new one. Old cells wear out and new ones are produced to take their place. Even some of the cells of our teeth are different ones this week from the ones that were in the same places last week.

Of course it is only the *first* stage of digestion that takes place in the mouth: other stages take place in the stomach, the duodenum, and the small intestine.

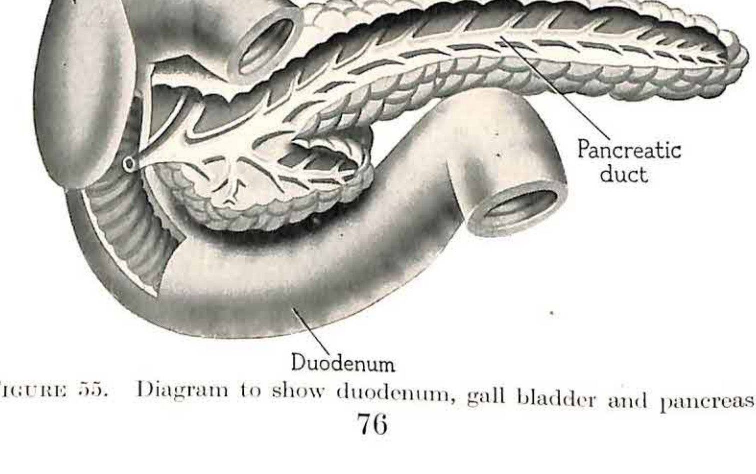


FIGURE 55. Diagram to show duodenum, gall bladder and pancreas.

Fats and proteins must also be transformed before being taken up by the blood. The other constituents of food, namely minerals and vitamins, can be absorbed into the blood after little or no change.

One of the enzymes in the stomach itself is rennin. This enzyme causes milk to clot or curdle, and another enzyme, pepsin, converts proteins into soluble substances called *peptones*. You will recall that lean meat consists mainly of protein, though there is some fat interwoven among the muscle fibres. Other important sources of protein are eggs, milk, cheese, peas and beans, and we also obtain protein in the " germ " of grain seeds (see Figure 36), in the layer of cells just below the outer skin of potatoes, in various parts of fruit and nuts and in fresh vegetables.

Fats are digested by substances produced by the liver and the pancreas, and the pancreatic enzymes also play a final part in the digestion of carbohydrates. Then also there are other enzymes produced by the small intestine. The final effect of digestion is to reduce food into a state in which it can pass from one cell to another and the absorption of the digested food into the blood is brought about by the remarkable lining of part of the small intestine.

HOW THE FOOD GETS INTO THE BLOOD

Look at Figure 56. This shows you that parts of the lining of the small intestine are not smooth like the skin on our arms or thighs, but are more like velvet. Velvet too is smooth to the touch ; but if you examine it with a lens, you will find that its " pile," like the " pile " of a carpet, consists of upstanding threads. Each of these threads in the intestinal lining is called a *villus*, from a Latin word meaning " shaggy hair."

But, as Figure 56 shows, every upstanding villus

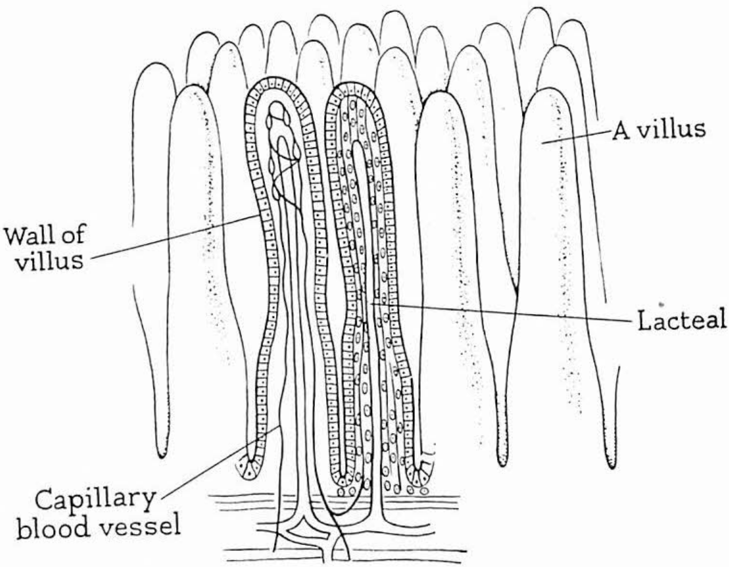


FIGURE 56. Diagram of a portion of the wall of the small intestine highly magnified, showing villi.

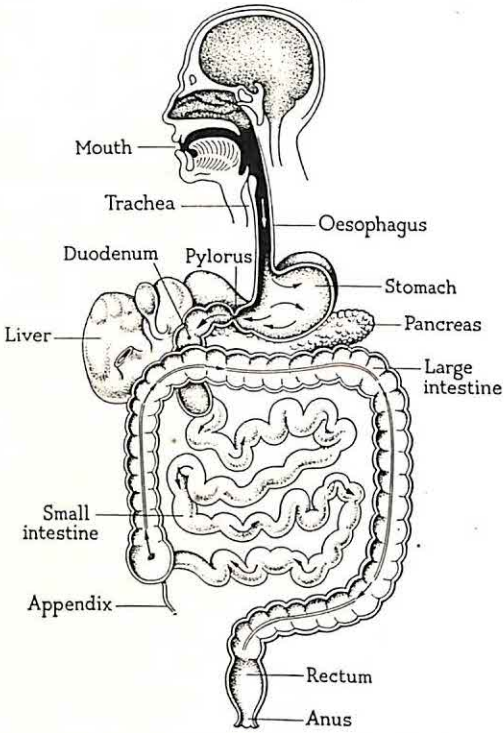
when magnified appears somewhat like a small lighthouse in shape. The villi in small intestine removed from the human body average in height about one-hundredth of an inch. Experiments show, however, that in living tissue the villi undergo continual stretching upwards and downwards, so that at times they are more than double this height. This is part of the way in which they "capture" digested food substances, which they then pass either into the minute blood vessels or into the lymph spaces (see Figure 56). The absorption takes place through the tall column-like cells that make the surface of villi. Each of these cells has a narrow outer border with fine lines running through it and an oval-shaped nucleus at the other end of the cell. We have now traced the processes of digestion to the end, for the *lacteals*, or minute lymph spaces, and the minute blood *capillaries* of the villi

all flow into large lymphatic channels or larger blood vessels and so join the blood fluid which is distributed all over the body. It is in this way that all the cells of every part of the body are fed, whether they be cells of the brain, or of the liver, or those in the bone marrow that make the red cells of the blood, or those of the voluntary muscles that make up our flesh.

FUNCTION OF THE LARGE INTESTINE

But as well as having a small intestine, we have a large one also. Yet we have now come to the end of the story of digestion, so you may ask why we have a large intestine as well (see page 80). Its main purpose appears to be to extract water from the undigestible material that has been passed into it by the small intestine. This is part of preparing this waste material for passing out of the human body. The waste consists largely of matter which is not acted upon by the various enzymes. Some of it, like the cellulose of vegetables or the bran of wheat, we call *roughage*. Human beings cannot convert this into food substances, but it is very important in providing bulk for the various glands of the stomach and intestine to act upon. Diet which does not contain a certain amount of roughage generally leads to constipation and this often leads to other illnesses.

Some animals, however, by the aid of colonies of bacteria and of other unicellular organisms living in their digestive tracts, can convert a certain amount of cellulose into food. As cellulose is a principal constituent of the stem of grasses you can doubtless suggest the names of some of these animals. Would you include geese ? Termites can also digest cellulose in much the same way.



Redrawn from Davies: "Hygiene and Health Education" *

FIGURE 57 (*a*). A diagram to show the human digestive system.

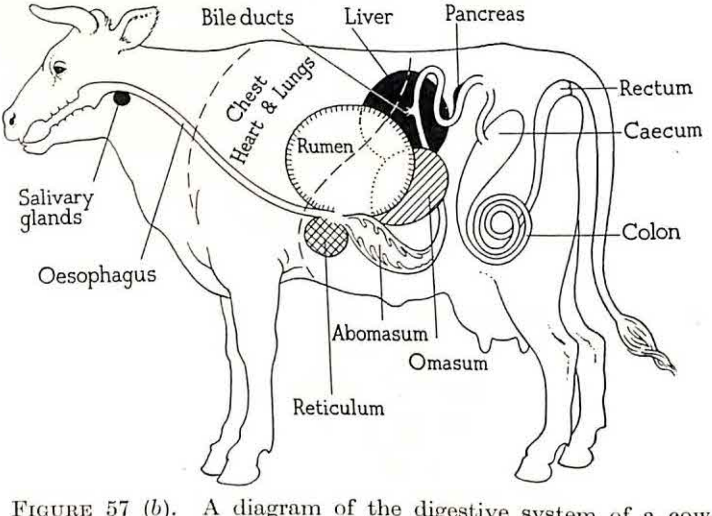


FIGURE 57 (*b*). A diagram of the digestive system of a cow.

1. The simplest test for the presence of starch is a few drops of a solution of iodine in potassium iodide. Put a few drops of such solution on a fragment of starch, on a piece of bread, a piece of blotting paper, a slice of apple, a fragment of raw potato, a fragment of boiled potato, some white of egg, some cheese, in a drop of milk. Compare your results.

2. The presence of glucose sugar can be established by another simple chemical test. This uses Fehling's solution (which your teacher will no doubt provide). Add a few drops of Fehling's solution to half an inch of glucose solution in a test tube. Then gently heat the liquid in a bunsen flame till it boils. Observe what happens. Now chew a little bread for a few minutes and then spit it out into a funnel fitted with filter paper and add a little water and let this filter through. Then repeat the test you applied to the glucose solution. Finally soak some bread in water and then filter the water and again test with Fehling's solution. What have you discovered ?

3. Buy some rennet from the chemist and carry out the instructions for making junket. Observe what happens ; this is what happens to milk in the human stomach. Find out how rennet is produced.

4. You may be surprised by the high water content of many foods. Test some potatoes, cabbage, turnip, cereals, etc., by taking a weighed quantity and drying it on a flat tray over steam. Weigh again and from the loss in weight work out the moisture content as a percentage. Is water important for growth ? Why ?

5. Perhaps several of the class, working together and with the help of your librarian, can prepare a talk on " Cellulose ; what it is and how some animals use it as food."

Question 3. **What things Regulate Growth ?**

From what you have already discovered you will see that one of the most astonishing things about the development and growth of an animal is the way in which the various kinds of cells appear at the right time and go on multiplying rapidly for just the right period. After that, without growing bigger, they replace themselves by new cells just at the right speed to keep the given organ, for example a kidney, at the right size and working in the right way. All this happens in such a smooth and orderly way that we take it all for granted and seldom stop to wonder at the marvel of it. We often express amazement at the complexity and apparent skill of various kinds of machine, yet there is no machine so complicated or wonderful as the living body of a mammal.

Despite all the fascinating recent discoveries concerning living bodies, we still do not know the full story of how the human embryo turns into a baby, complete with all its limbs and organs. But we do know a good deal regarding the development of the baby into a child and regarding the growth of a child and the gradual changes into an adult.

It seems that the growth of the different parts of the body is regulated by chemical messengers which are sent in the blood stream from one part of the body to another. Among these chemical messengers the most important are those produced by *endocrine glands*. A *gland* is a group of cells producing fluid. Tears come from a tear gland, saliva from a salivary gland. When children have swollen glands of the neck it is usually the salivary glands which are affected. The special sort of glands called *endocrine* are named from Greek words that mean " within " and " to separate." If

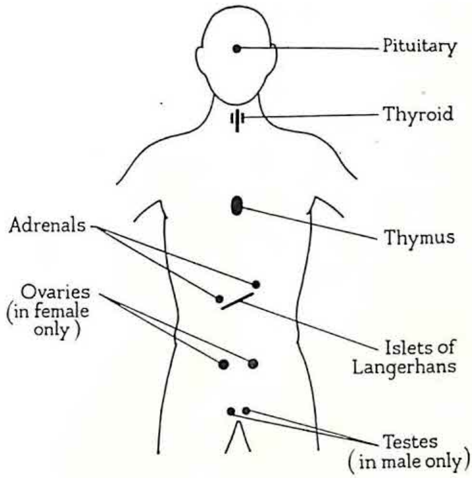


FIGURE 58. Diagram to show positions of endocrine glands.

you look at Figure 58 you can see that the endocrine glands are, with one exception, clearly separate from one another and are, in fact, in different parts of the body. The endocrine glands have a most profound effect upon our lives at all stages and there is a vast and increasing amount of knowledge about them. Here we can select only a few facts about ways in which some of them affect our growth.

The thymus. This is a gland that possibly acts during the growth of a baby and a small child, but seems to have little or no importance in the adult. It forms two large masses in the upper part of the thin skin (or membrane) which divides the chest into two parts. In babies this organ grows rapidly till the child is two years old; then much more slowly. From the time that a young person commences to mature (an age which varies from 11 to 14 or so) this gland decreases in size. By the time we are fully grown, only small stumps of it remain. But clearly it must have had some special task to perform in early childhood.

The thyroid gland. This is a small butterfly-shaped

gland which lies on either side of the Adam's apple. The two lobes are joined by a narrow strip of gland which lies across the Adam's apple itself.

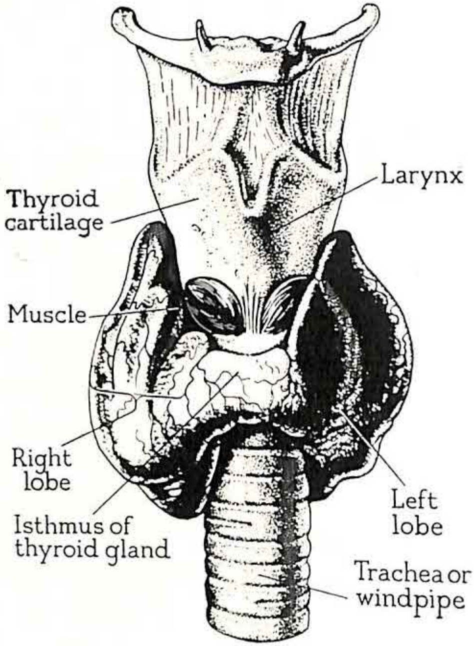


FIGURE 59. Diagram to show human thyroid gland.

The thyroid gland, from the stage of birth and probably before that, is one of the most important regulators of growth. If you look up in a fairly large dictionary the word *cretin* you will probably read that it means a dwarfed child which is physically and mentally defective. These children just do not grow up properly.

Fortunately such children are rarely to be found today in countries which are fairly up-to-date in their scientific knowledge. For about thirty years ago it was discovered that this dreadful failure to develop was due solely to deficiency of one of the chemical messengers produced by the thyroid gland. The name

usually given to a chemical messenger is *hormone*, from a Greek word meaning " set in motion." It was found that if cretin babies were given an extract of the thyroid gland of an animal, then they would immediately start to develop into normal human beings.

It had long been known that cretins were most common in Alpine villages. One reason for this turned out to be the lack of small traces of a certain substance in the food of the mother and of the child. This substance proved, astonishingly enough, to be iodine. Now iodine occurs abundantly in seaweeds and in sea fish, and there are traces of iodine in most drinking water. But it may be completely absent from the food and the drink in high mountain villages where the drinking water comes straight off the rocks without soaking through the earth and so dissolving in it any minerals. In these high villages, too, sea fish was a rare and expensive food.

In adults lack of iodine may result in the thyroid gland expanding and giving a thick neck, or a great swelling on the neck known as *goitre*. These troubles used to be fairly common in isolated villages in Derbyshire and in Somersetshire mainly because there was no trace at all of iodine in the drinking water in large areas of those two counties. Nowadays such diseases are rare in those areas. The change has been brought about to some extent by providing more suitable drinking water, and by the use of iodized table salt.

The *parathyroids* are four small bodies almost buried in the back part of the thyroid. They play a part in controlling the strength of bone. If they produce too much of their particular hormone, bones become soft and deformed and readily break.

The pituitary body. Figure 60 shows you the pituitary gland as a tiny body lying at the base of the

brain. For centuries no one had any idea of its purpose. Now we know that it produces at least six different chemical messengers and probably directly affects most of the other endocrine glands and so "conducts the endocrine orchestra."

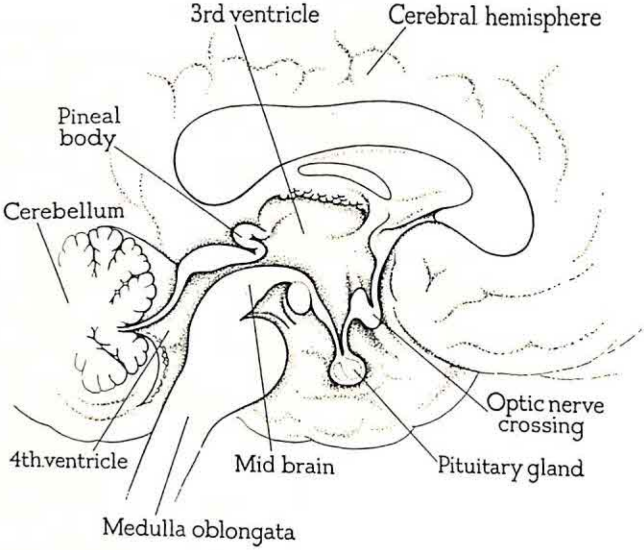


FIGURE 60. Diagram showing the position of the pituitary gland near the base of the midbrain.

Actually the pituitary body has been found to consist of two distinct parts, a front lobe and a back lobe. It is the front lobe that controls the growth of the skeleton in young people and also directly affects the thyroid and other endocrine glands. If this lobe produces too much of one of its hormones before a young person begins to mature, his bones grow too long. Before scientists had discovered the cause some young people became excessively tall, such as seven feet high, without being properly proportioned. If there is too much of this hormone after maturing has commenced, then only certain bones grow too much, such as those of the hands or feet.

Nowadays such overworking of the pituitary can usually be found at an early stage and remedied.

The pituitary gland also has a great number of other effects both on birth and on growth. For instance it has recently been discovered that it is the gland that gives animals, including birds, their mating season. We are not yet certain how it works, but we know that the effect of the brighter and longer days of spring is somehow communicated to the pituitary gland which sends a message to the testes and to the ovaries and these, in response, begin to get active. In mammals the pituitary gland plays a big part in preparing the milk supply of females that are going to be mothers.

Endocrine products from the ovaries and testes. We know that the main purpose of these organs is to produce either egg-cells (ova) or male cells (sperms). But, in addition, there are special cells of these organs which, like the pituitary or the thyroid, produce chemical substances which have an effect upon other parts of the body. The fact that boys develop hair on the face and that their voices "break" (i.e. the vocal chords stretch) is entirely due to the hormone produced by the testes, or testicles, as they are called in man.

Similarly the effect of the special endocrine cells of the ovary is to bring about certain definite feminine characteristics such as limbs with more rounded shape due partly to a thin layer of fat beneath the skin, an absence of hair on the lips and chin, and so on. Disease of the ovary may result in the development of a certain amount of facial hair.

We may sum up these effects of the hormones of the sex glands by saying that they control the development of maleness or femaleness.

The effects of the pancreas. It is important for us to

keep in mind that the action of all the endocrine glands is extremely complicated. But we can isolate one or two simple facts, such as the discovery made less than forty years ago that the disease known as diabetes, which up till then had been considered hopeless, can be completely controlled by doses of a hormone produced by the pancreas of an animal. Today hundreds of thousands of people are living normal lives thanks to regular doses of *insulin*, the hormone manufactured by the pancreas, and now made artificially in laboratories.

The adrenal glands. These, like the pituitary body, were known for a very long time before it was suspected that they had any great importance. They are twin bodies shaped like a cocked hat (see Figure 61) situated just above the kidneys of mammals. They produce chemicals which are of very great power indeed in their influence on the body. The direct effect of one of these

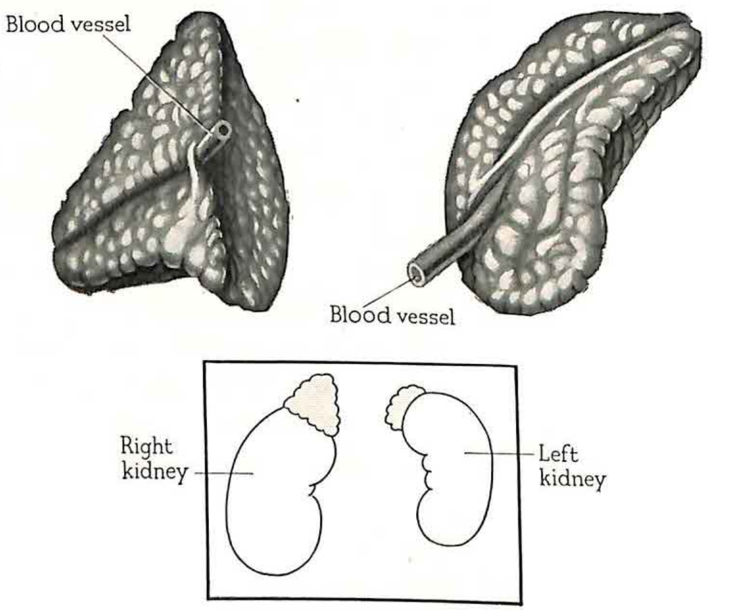


FIGURE 61. Adrenal glands and their position with relation to the kidneys.

is to tighten all the minute muscles that, throughout the body, affect the blood supply. If one millionth of a grain (and it takes 480 grains to make an ounce) of this substance, adrenalin, is injected into a rabbit, every blood vessel of the animal will be temporarily tightened. In proportion to the bulk of a rabbit this would be like adding one drop of water to the boiler of one of the largest steam locomotives.

In human beings adrenalin has a similar effect. When we become angry, adrenalin is let into the blood stream. It is this that tightens the blood vessels, that causes the face to flush, and that makes the muscles taut so that we find ourselves ready to strike whatever is offending us. All this action of adrenalin puts a strain, of course, on the nervous system, and people who allow themselves unnecessarily or frequently to get angry are doing themselves harm as well as upsetting other people.

"BALANCE" AMONG THE ENDOCRINE GLANDS

The fact that the amount of adrenalin in our blood at any time is to some extent under our own control leads us to ask if we can control, to any extent, the amounts of chemical poured into our blood stream by other endocrine glands, such as the thyroid and the pituitary. We do not yet know of any such control, but we do know that in good health there is a sort of balance established between the hormones, and that one hormone may affect the production of others. Since our "thinking" *can* to some extent affect the amount of adrenalin in our blood, it can probably, indirectly, affect other endocrine glands and so affect our health as well as our personality.

Moreover, recent studies on the pituitary gland have

shown that it is possible that cells of the brain itself lying near the pituitary gland may also be producers of hormone. If this should prove to be well founded it may lead to greater understanding of the way in which the brain affects the body chemically.

Everybody knows how the brain controls the "voluntary" muscles, such as those of arms and legs, by means of the "telegraph system" of the nerves. It is the "involuntary" muscles, like those of blood vessels and the stomach, that are affected most by hormones.

If the production of hormones is to some extent directly affected by the thoughts which we allow to linger in our minds, then this fact would emphasize still more how important is the human will. It is this possession of self-control, based upon reason, which distinguishes men from most animals. And only so far as men and women, the world over, use reason and unselfish ideals more and more to control their impulses can humanity advance.

SOME THINGS YOU MAY CARE TO DO

1. Look up the word *iodine* in an encyclopaedia and so prepare a talk on this subject to your class. You can also get free information about iodine from an organization which exists to increase the sales of substances containing iodine. This is the Iodine Educational Bureau, 20 Ropemaker Street, London, E.C.2.

2. Look up the word *goitre* in an up-to-date encyclopaedia. Then ask your librarian if she can find you books which will help you to find out what foods contain any iodine.

3. The word *hormone* is now widely used by gardeners in connection with plant hormones. Some of these

are used to promote the growth of plants for sale. Some hormones stimulate root growth of cuttings. Call on your local seedsman and see if he can give you handbill advertisements regarding plant hormones and paste these, with your own comments, in your science notebook. Best of all, experiment with some of these yourself in your garden, or with plants in flower pots.

Problem D : What do we know about Human Growth ?

Question 4. **How does the Human Mind grow ?**

Everyone knows that the mind, through the nerves, directly affects the body. We have seen that the mind can also have a direct effect upon the chemicals circulating in the blood. Can you recall how this happens ? In the reverse way the chemicals circulating in the blood can have a direct effect upon the mind, although the lives of saints and martyrs show us that the mind and spirit can, and should, dominate the body, whatever ills the body may be enduring.

Still, in the case of a little child, and even more in the case of a baby, the mind is almost entirely at the mercy of the body. When the baby is hungry, or cold, or lonely, it cries. When a child feels neglected, it does things to call attention to itself, even if those things are not the things that we should wish it to do, such as throwing a cup and saucer from the high chair to the floor. It is difficult to know how to act wisely in helping a little child's mind to grow in the right way. Scolding and beating will make a child sullen,

FIGURE 62. A baby showing frustration.
W. Suschitzky

mistrusting, and cruel; on the other hand too much freedom may make him "spoilt."

Fortunately there is one fact about the development of the mind which has been so firmly established by psychologists that we can act upon it with complete assurance. This basic fact is that healthy growth can only take place in security provided by unselfish love.

It is an astounding statement of psychologists, but perhaps completely true, that the very basis of a child's character is laid in its *nursery years*. By this is meant the pre-school years. Researches into the lives of criminals and of young people in remand homes and approved schools have shown, in many cases, but of course not in all, that things started to go wrong at home in very early years. In most cases, of course, we cannot obtain information regarding *how* a baby was treated by its parents in its first year or two. Still, increasing evidence continues to show, more and more, how very important it is that babies should be handled rightly and with love and understanding from the very day they are born. In most counties great care is given nowadays to the *physical* welfare of expectant mothers and later to their babies' physical health. But in only a few places have authorities started to help future mothers and fathers to know how to look after the *mental health* of their little ones. Indeed, in most large towns child guidance clinics are overworked because so many parents, by wrong handling of their little ones in the first few years, are producing so many problem children. At one clinic the psychologists reported that more mothers came for advice regarding little children aged about two years than about children of any other age. This merely emphasizes that these early years are especially tricky and call for considerable understanding on the part of

the parents. One of the difficulties of this period is that children at this age already know what they want but have not enough command of words to explain.

Advantages of understanding how the mind grows. The baby's mind is ready to try to understand sounds from almost the commencement of its life. Indeed, for a very small baby, hearing is more important than seeing and it soon learns to recognize friendly noises and rhythmic movements and noises and the tunes of lullabies. By the age of six months the baby's mind is helping it to make all sorts of noises itself, some in imitation of what it hears and some which could belong to the language of another race thousands of miles away.

But some children are born with hearing that does not work properly, though their external ears may look normal. By knowing what responses a baby should be making month by month, if it is completely healthy, experts can soon notice if a baby's hearing is not right. It is very important to find this out as soon as possible, because at the age of six months and onwards a baby's mind is just at that stage of development when it is learning that certain signs or certain sounds mean certain things.

Even a completely deaf baby can learn to understand what its mother says, by lip-reading, provided that the mother speaks directly to it without mumbling. Later, provided it can see people's lips, it can learn to understand and take part in ordinary conversation.

FIGURE 63. Quite small deaf children now learn to use hearing aids.
Nucleus Photographs Ltd.

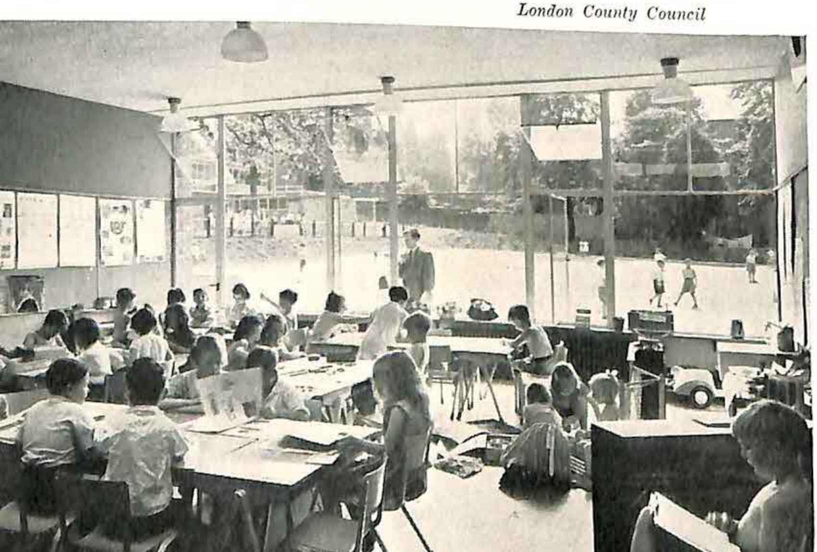
Nowadays, too, it can, if not completely deaf, be assisted by hearing aids, even from the age of a few months.

This is an example of the way in which the study of the growth of the human mind is making life less difficult for thousands of unfortunate children in scientifically advanced countries. In the scientifically backward countries there are thousands of babies who need similar help.

Growth of the mind during primary school years. The first stage of the growth of the human mind is based, we have seen, on a sense of security built up by being surrounded with love. Then, when the child reaches school age, he sallies forth with a certain sense of confidence to enter upon the adventure of being one of a whole class of children. This means new experiences and the discovery of new powers of body as well as of mind. Then comes learning to sing, learning verses and learning the multiplication tables. For Nature has provided that the child's mind, between the ages of five and nine, finds delight in learning things by heart, whether they be nursery rhymes or even a list of railway stations. Children, when they

FIGURE 64. A class in a modern primary school in summer.

London County Council



have learned things by heart, feel a sense of mastery and pride and some of that sense of security which is so important when they are young. Things that they have learned by heart have become, they feel, part of themselves, and they are proud of these possessions. You have no doubt met little children who beg you to listen to them repeating something or other, whether it be a verse from the Bible or the names of their friend's pet rabbits.

So, for most normal healthy children, learning both at school and at home should be a very happy and easy process, especially up to the age of 9 or 10 years.

The growth of the mind during secondary school years. After that time, at ages which may be anything between 10 and 15, young people begin to " mature." The ovaries of girls and the testicles of boys begin to send their chemical messengers about the body. The breasts of the girls begin to develop, preparing well in advance for the time when they may become mothers, and the womb begins the process of shedding its innermost layer about once a month, with the loss of a little blood.

In boys, usually a year or two later, discharge of material formed by the testicles begins to take place occasionally at night. At the same time the voice begins to break, the muscles of the body begin to become more pronounced and workmanlike and hair begins to grow on the top lip, on the chin, and the cheeks. Some boys of this age, wishing to emphasize to their friends that they are growing up, think it necessary to smoke cigarettes. But in view of all we know today about the relationship between smoking and cancer, they would be well advised never to take up this habit. Can you think of better ways in which boys can show that they are growing up ?

The developments of the "teen" years, associated with greater reserves of power and with greater muscular strength, give rise to the desire of young men to accept more responsibility for themselves and to lay plans for their full manhood. Particularly they often wish to see clearly the ways in which their studies will help them, later on, to earn their own living and become a full citizen.

During these years of adolescence both young men and young women generally find themselves more able than they were when children to appreciate poetry, art, drama, and music. They also begin to think deeply about the big problems of life, including its religious, social and international aspects. Moreover they form opinions on how life might be made better for everyone and what their own contribution towards such advances might be. These things are important, for the thoughts of youth influence our actions for the rest of our lives. That is one of the reasons why class discussions are very useful, especially if the scientific attitude, which demands facts on which to base opinions, is steadily maintained wherever possible.

SOME QUESTIONS FOR DISCUSSION IN CLASS

1. Since the most important things a baby needs, after food and clothing, are to have the security of a home with both mother and father and to be surrounded by love in the first few years of life, what can be done (*a*) by governments, and (*b*) by individuals to strengthen home life ?

2. What opportunities should young people of fourteen years of age and upwards be given of helping to increase the happiness of the community in which they live ?

SCIENCE ON THE MARCH

The Air and You

Water and Life

The Weather and the Earth

Life and Food

Health

Energy and Engines

Hearing and Seeing

Electric Currents

Magnets and Electric Power

Earth and Universe

Heating and Cooling

Birth and Growth

Metals and Man

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